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Human Factors of Cockpit Automation: A Field Study of Flight Crew Transition

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SUMMARY

This was a field study involving two groups of airline pilots over a two-year period to determine what factors affected their transition from traditional airline cockpits to a highly automated version. All were highly experienced in traditional models of the McDonnell-Douglas DC-9 (-10, -30 and -50 models) prior to their transition to the more automated DC-9-80 (MD-80).

Results and conclusions dealt with specific features of the new aircraft, particularly the digital flight guidance system (DFGS) and other automatic features such as the autothrottle system (ATS), autobrake, and digital displays. Particular attention was paid to the first 200 hours of line flying experience in the new aircraft, and the difficulties that some pilots found in adapting to the new systems during this initial operating period. The lack of a DC-9-80 simulator at the beginning of the study, and its subsequent availability to pilots who transitioned later in the study was a salient feature of the project. Other findings involved efforts to prevent skill loss from automation, training methods, traditional human factors issues, and general views of the pilots toward cockpit automation.

CONTENTS

I.	INTRODUCTION	1
II.	BACKGROUND TO PRESENT STUDY	3
	Choice of Super 80	3
	Super 80 design philosophy	3
III.	STUDY METHODOLOGY	5
	Data sources	5
	Longitudinal analysis	5
	Panel formation	6
	Confidentiality	7
	Questionnaire development	7
	Interviews	8
	Table 1 - 36 Likert items	9
	Data handling	11
	Figure 1 - First page of Likert scale	12
	Figure 2 - Percent use scale	13
IV.	QUESTIONNAIRE RESULTS	14
	Table 2-A and 2-B - Likert scale results	16
	Table 3 - Likert scale by logical groupings	18
	Figures 3-A to 3-F - Likert scale results	19
	Table 4-A and 4-B - Frequency-of-use results	24
	Table 5-1 to 5-5 - Open ended question results	27
	Table 6 - Unsolicited comments	42
V.	CHECK AIRMAN INTERVIEWS	44
VI.	LINE PILOT INTERVIEWS - Wave One	50
	- Wave Two	64
VII.	DISCUSSION	74
	Opportunities and hazards of field studies	74
	Pilot opinion	75
	Overall view of automation	76
	Perceived workload and fatigue	78
	Figure 4 - MUSEL Four departure (Santa Ana, CA)	80
	Skills maintenance and erosion	82
	System reliability	85
	Specific features	86
	Figure 5 - Flight guidance and control panel	88
	Figure 6 - FGS warning and annunciation	89
	Psycho-social factors	90

VIII.	CONCLUSIONS	92
IX.	NOTES AND ACKNOWLEDGMENTS	98
X.	REFERENCES	101
XI.	APPENDICES	102
	Appendix 1 - Automation principles (Wiener & Curry)	103
	Appendix 2 - Project data management	105
	Appendix 3 - Glossary of DC-9-80 terms and abbreviations	106
	Appendix 4 - DC-9-80 automatic flight systems	108
	Appendix 5 - Intercorrelation matrices of attitude data	110

I. INTRODUCTION

The microprocessor revolution of the 1970's offered commercial aircraft and avionics manufacturers the opportunity to design and implement small, special purpose digital computers for the flightdeck. These computers made it possible to automate many of the functions previously performed manually by the flightcrew, and as well to provide the logic for warning and alerting systems that, in effect, worked in parallel with the pilot. In addition, flight instruments driven by digital computers allowed the designer to display digitally information which previously had been present analogically, mostly on pointer-type instruments.

Thus, the new generation of automated, microprocessor-based transport aircraft went far beyond previous generation of automatic equipment, such as autopilots, flight directors, and altitude alerters. The potential has only begun to be exploited. For example, the potential fuel savings of 4-D navigation and microwave landing systems (MLS) is now being addressed, partly because the airborne equipment has not yet been perfected, but mainly because the ATC system does not yet allow full exploitation of flight-deck automation.

By the end of the 1970's, many in the aviation field, and in government, were beginning to be concerned about certain safety implications of the march toward automation. There was evidence from aviation accidents and incidents, as well as words of caution from members of the human factors profession (Edwards, 1977), that human error could not be automated out of the system, and indeed, design and installation of automatic devices in the cockpit, without proper human factors principles, could increase rather than decrease, the potential for human error. Questions were also being raised about whether automation would necessarily reduce crew workload.

In 1977 a House of Representatives subcommittee gathered opinions from various segments of the aviation industry on their areas of concern for commercial flight safety (Anon, 1977). One of the areas that stood out was automation. These concerns were voiced again in a Senate subcommittee (Anon, 1980). As a result of these hearings, and other concerns about the safety impact of automation, in 1979 NASA was directed to examine the human factors of automation. An automation group was formed at the NASA-Ames Research Center, under the direction of Dr. Renwick Curry. Dr. Curry and the author, then on leave from the University of Miami, published a paper (Wiener and Curry, 1980) in which they outlined the benefits and potential problems of automation on the flightdeck, and drafted 15 tentative principles (previously called "guidelines"), which are reprinted in Appendix 1 of this report.

In order to seek further information and opinion on the

potential human factors problems of automation, NASA held a joint industry-NASA workshop on flightdeck automation in the summer of 1980. A small group of experts from industry, government, airlines, academic institutions, and NASA examined the issues and drafted a report which generated questions that would require research in the years to come (Boehm-Davis, Curry, Wiener, and Harrison, 1981).

In this report, no effort has been made to provide a comprehensive review of the literature and state-of-the-art of cockpit automation. This can be found in the papers by Wiener and Curry (1980) and Wiener (1985).

Purpose of the Research

The purpose of this research was to gain information on the human factors of automated cockpits. The particular issue under study was the transition of pilots from a traditional technology aircraft (DC-9-10, -30 and -50) to a highly automated derivative model. The DC-9-80 is used here as a "laboratory" to study crew transition. The study is not intended as a critique of the DC-9-80 design per se. However, in collecting questionnaire and interview data, it was inevitable that the crews would discuss in minute detail the particular systems of this aircraft. It is impossible to conduct an "aircraft independent" project of this sort. The author feels that most of the comments regarding DC-9-80 systems can be interpreted as generic statements regarding flightdeck automation.

Also, the results of this study may not be entirely "airline independent", as they are the product of one airline's experience in adapting to a new technology aircraft. It is inevitable that there will be problems as well as successes in integrating a new aircraft, particularly one employing a new technology, into an airline's fleet. The problems, as reflected in some of the negative comments made during interviews (see Section VI), should not be construed as criticism of either the host airline or the manufacturer. Two points should be made regarding some of the comments in the interview section:

- 1) Most of the training problems mentioned by the check airmen and line pilots were the consequence of not having a DC-9-80 simulator available. This was remedied later in the study period, and a much more positive view of both the training and the aircraft emerged in the second phase of data collection as a result of this.
- 2) As the pilots became more experienced in the -80, most of the negative sentiments vanished.

II. BACKGROUND TO PRESENT STUDY

The Choice of the Super 80

NASA scientists felt that many of the questions posed by the workshop could best be answered by field investigations with air carriers, rather than laboratory work. In 1980 the introduction of the McDonnell-Douglas DC-9-80 (Super 80) presented a golden opportunity for such a field investigation. (In 1983 Douglas redesignated the aircraft the MD-80. For the sake of consistency, this report will use the traditional designation). The Super 80 was designed for the short and medium haul market, and would bring to the carriers serving these markets an aircraft with electronic and avionic sophistication previously seen only a widebody transports. The intended market, consisting mainly of regional carriers, made the -80 especially attractive as a study vehicle, since it would be flown primarily by flight crews transitioning from older, less automated aircraft such as Boeing 737s and 727s, and older models of the DC-9. For this reason we would have the opportunity to study the reactions of pilots who were flying sophisticated avionics for the first time (excluding possibly military experience). This was in contrast with the larger trunk carriers, where many flightcrew members, especially very senior first officers and very junior captains, might have had right-seat experience in sophisticated widebody aircraft.

At a meeting of the Operations Forum of the Air Transport Association (ATA) in 1980, Dr. Alan Chambers revealed the desire of his division to work with a carrier planning to buy the DC-9-80. Capt. John Hanson, then Director of Flight Standards and Training at Republic Airlines, expressed an interest, and shortly after Curry and Wiener made a formal proposal for a cooperative study to Republic's flight operations management and the Republic/ALPA Safety Committee. In April 1981 the author attended a three-week pilot training course on the Super 80 at Douglas Aircraft in Long Beach, and the work with Republic began in early 1982.

The Super 80 Design Philosophy

In order to understand the great value of the Super 80 for this study, it is necessary to discuss briefly the design philosophy of the plane, and its place in the crew complement ("two vs. three man") issue. With the introduction of digital systems into the cockpit, the question of crew workload, and hence crew size, was emerging as an issue between manufacturers, air carriers, and pilot unions in the U.S. and worldwide. Both airplane and avionics manufacturers were stressing the promise of automation in achieving workload reduction, and it became clear

that their intention was to request certification for aircraft with two-pilot crews. An article on the Super 80 avionic system appearing in Aviation Week and Space Technology (Smith, 1978) well before the appearance of the Super 80, was entitled, "Digital system used to cut workload." Douglas, as well as Sperry, the designer of the digital flight guidance system (DFGS), based their design philosophy on workload reduction through automation. This was due to concern for the safety of aircraft operated by regional carriers, which by the nature of their operations, typically spent a large portion of each leg in climb and descent in high-density terminal areas. The collision of a PSA Boeing 727 with a Cessna 172 over San Diego in 1978 intensified the desire to reduce cockpit workload, allowing more time for extra-cockpit scanning. But clearly the manufacturers and potential customers also sought to head off any argument that the Super 80 should carry a third pilot, the position adopted by the Air Line Pilots Association (ALPA), though not all of its individual executive councils. The purpose in mentioning this is to stress the emphasis on workload reduction in the design phase. A more thorough discussion of workload and the crew complement question can be found in Wiener (1985).

The issue was eventually settled by the President's Task Force on Crew Complement (McLucas et al., 1981) and the FAA's certification of the -80 as a two-pilot aircraft. The Presidential Task Force based its decision largely on the demonstrated safety record of two-pilot aircraft, and the assumption that workload was not likely to increase in future models. The assumption that the flightcrew's workload is reduced in any aircraft by introducing automation was challenged by Wiener and Curry's report (1980), in which they argue that workload may not be reduced at all, but merely relocated in time (for example, programming at the gate, rather than in flight). Likewise, the nature of the workload may be changed, as for example, reducing manual operations, but increasing the need to monitor the equipment. This viewpoint was expressed recently by the National Transportation Safety Board in its recommendations following a DC-10 overshoot accident at Kennedy Airport (NTSB, 1984). The author begins with the position that it should never be assumed the automation reduces total workload. This is one of the primary questions to be addressed by the present study.

III. STUDY METHODOLOGY

Data Sources

Since this study focussed on the adaptation of flightcrews to the more highly automated environment of the -80, most of the data were collected directly from crew members -- including line crews and check captains. The following sources of data were originally proposed:

- a. cockpit observations
- b. structured interviews with crews
- c. questionnaires filled out by crews
- d. interviews with check captains
- e. interviews with simulator instructors
- f. maintenance logs
- g. check pilot meetings

Of these proposed sources of information, only the first four were examined extensively, for the following reasons. Since Republic's -80 simulator was not installed until May 1983, interviews with simulator instructors were not pursued. Maintenance logs did not prove to be a valuable source of information. A sample maintenance log (ATA Chapter 22 items) of one aircraft (No. 301) was examined and was deemed not to have potential for this study. Minutes of check pilot meetings were useful principally for formulating questions to be asked in interviews with check captains.

Longitudinal Analysis

Early in the project it was decided to design what is known as a "longitudinal analysis." This study method involves forming a study group, usually referred to as a "panel," and collecting data from them over several points in time. The value of a longitudinal study is that it permits the investigation of changes within individuals, rather than comparing groups of different individuals at points in time (called a "cross-sectional analysis"). In this research, intra-individual differences seemed important -- we were interested in how one's approach to and adaptation to cockpit automation changed over experience (and hence time). By starting early, we would be able to collect our first sample of data (called a "wave" in longitudinal analysis) early in the pilot's experience with the -80.

The disadvantages of a longitudinal analysis should also be mentioned. Longitudinal studies tend to be expensive; they require a panel who will remain with the study through its several waves; and in spite of dedication, some panel members are inevitably lost over the length of the study for a variety of reasons, including illness, retirement, or reassignment. In

addition, there are inevitable gaps in the data, due to some panel members, for one reason or another, failing to fill out questionnaires or not being available for interview, yet remaining in the panel for future waves. Also, continuing support from the host organizations is mandatory. And finally longitudinal methods require a continuity of the investigative staff, especially when field observations and face-to-face interviews are required, and hence standardization is essential.

Panel Formation

Pilot volunteers were contacted by a direct mailing from the Republic Central Air Safety Committee of the Air Line Pilots Association (ALPA), which acted as a go-between, linking the pilots with the investigators throughout the study. A booklet explaining the purpose of the study and carrying a cover letter bearing the endorsement of the management and the union, went out to the original group of pilots (approximately 100) who had received -80 training. Unfortunately, due to post-Deregulation economic conditions, the company drastically cut its order of -80s, receiving only three initially in 1981, and three more in December 1982. Consequently, many of the original trainees had not flown the line in the -80 at the time of the first appeal for volunteers, and many of the remaining trainees flew only a minimal number of trips in the -80. Thus the original appeal yielded only 30 volunteers, and some of these never flew the -80 in line operations.

In the summer of 1982, and later in December of 1982 and January 1983, more pilots entered differences training, and eight of these joined the panel, but not in time for the first wave of questionnaires, which went out in June 1982. Those who joined subsequent to that time received their first series of questionnaires at the same time that the original panel received their second, in June 1983. The mean flying time in the -80 of those responding to the first wave was 365 hours, with a mean total flying time of over 15,000 hours. The standard deviation of -80 time was 290 hours, indicating a great variation around the mean. The minimum was 37 hours, and the maximum was 1180 hours. Thus it can be seen that the mean experience level in the -80 was the equivalent of less than one-half year of full time line flying. See Table 2-B for the Wave Two flying time data.

In 1983 Republic decided to move approximately half of its Super 80 blocks to the Las Vegas domicile. This further reduced the number of Minneapolis pilots in the study panel who were actively flying the -80, but created an opportunity to form a new panel. With the approval and assistance of Republic's western Safety Committee, a panel of 13 volunteers based in Las Vegas was formed in the fall of 1983, and soon after first wave questionnaires were mailed out. Since Republic's simulator was not installed until May 1983, the first Las Vegas crews went through the differences program (training program for already

qualified DC-9 crews, stressing only the different or new features of the DC-9-80), but shortly after this the new Las Vegas crews went through the simulator-based program. Thus the Las Vegas study panel was composed of crews from both training programs. The role of the simulator in early line experience is discussed at length in this report.

Confidentiality

Confidentiality was ensured by having each pilot assign himself an eight letter/digit code when he initially joined the panel. Those codes were placed on all questionnaires by the respondents, but only the union Safety Committee had the code-to-name legend, and it was never seen by the author. It has since been destroyed. In the face-to-face interviews, the author knew the name of the pilot he was interviewing (it would be impractical to do otherwise), but did not know his code ID, and did not record his name on the interview form. In jumpseat observations, no record was kept of flight numbers, dates, or crew members' names.

Questionnaire Development

Three areas to be probed in soliciting aircrew opinions and practices were determined from the following sources: initial interviews with management pilots, jumpseat observations in older models of the DC-9, jumpseat observations in -80's of another carrier, and conversations with the crews, the experiences gained in attending the DC-9-80 school in Long Beach, and the questions generated at the NASA Industry Workshop. The three areas were: 1) attitudes toward automation in general, and the DC-9-80 cockpit in particular; 2) frequency of use of those automatic devices whose use was a matter of pilot option; and 3) pilot perception of workload and fatigue.

Numerous forms for the attitude scales were considered. Knowing pilots' disdain for paperwork, and mindful of our promise in the invitation to join the panel that participation would require only four to five hours a year, we sought to design forms that would be simple in format and would not require over one hour to complete. The final forms consisted of two instruments, a 35-item Likert-type attitude scale, and a 5-by-16 matrix frequency of use chart (see Figures 1 and 2). The Likert scale is an intensity type of attitude measurement, in which a statement is presented, and the respondent replies along a continuous scale from strong disagreement to strong agreement with the statement. The statements can be positive or negative toward the subject at hand. The advantages of the Likert scale is that it is easy for the respondent, allows a wide range of response (some forms use a multiple-choice restricted response), and is easy to score. The statements themselves were designed to probe several general (though somewhat overlapping) areas:

1. General attitude toward automation
2. General attitude toward flying as a profession
3. Specific attitude toward certain features of the -80, and specific items
4. General attitudes toward the influence of equipment on safety and economy
5. Influence of automation on workload, fatigue, and time to perform tasks, including extra-cockpit scanning

The 36 items are listed in Table 1. The frequency-of-use scale simply asks the crew member to indicate the frequency, in terms of percentages, of his use of 16 pieces of equipment. Frequency of use was considered crucial to the study for several reasons. First, the NASA-Industry Workshop participants had raised several questions regarding possible overuse and underuse of automatic options (Boehm-Davis, et al., 1981). Secondly, frequency of use is a variable that may show considerable change in a longitudinal study. We expected frequency of use of automatic features to increase over time, particularly between the first and second wave of data collection. Finally, it is the general policy of Republic management that automatic devices should be used (subject to captain's discretion, of course). Pilots referred to this policy as "we bought it, you use it", and this is discussed in later sections. Since the Republic -80 pilots all had considerable experience with earlier models of the DC-9, this scale, with this panel provided a particularly good opportunity to determine patterns of usage of equipment that they were encountering for the first time. There were problems in the interpretation of the instructions, which led to some questionable data on this form. This is discussed in Section IV.

Interviews

A structured interview form was developed for use with the line pilots, and was tested in interviews with management pilots. A structured interview is a compromise between a questionnaire (completely structured) and a totally unstructured interview. It imposes structure to the extent of making certain that all topics are covered, but allows the freedom of an unstructured interview to follow up points, seek clarification, and in general use interviewer judgement about pursuing points further, or ending discussion if need be. In the interviews with the panel, many valuable points were raised by the interviewees that would not have been revealed in a questionnaire or rigid interview.

The interviews with the check captains covered all of the points covered in the line pilot interviews, but also included

Table 1

The 36 Likert scale items

1. Flying today is more challenging than ever.
2. I miss the "good old days" of simpler aircraft.
3. I am concerned about a possible loss of my flying skills with too much automation.
4. I hand fly part of every trip to keep my skills up.
5. Hand flying is the part of the trip I enjoy the most.
6. I think they've gone too far with automation.
7. I can fly the airplane as smoothly and safely by hand as with automation.
8. It is important to me to fly the most modern plane in the company's fleet.
9. I look favorably on automation in the cockpit - the more the better.
10. I am looking forward to even more automation in future planes.
11. I wish we had full autothrottles on the 10s, 30s and 50s.
12. Younger pilots catch on to automation faster than older ones.
13. Pilots who overuse automation will see their flying skills suffer.
14. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate more on "managing" the flight.
15. I spend more time setting up and managing the automatics (such as the DFGS) than I would hand flying or using the old style autopilots.
16. Older pilots seem to resist the new technologies.
17. Automation does not reduce workload, since there is more to keep watch over.
18. Automation is the thing that is going to turn this industry around and make it profitable again.

19. Automation may be helpful in long-haul operations, but not in short-segment operations like ours.
20. All these new features are nice to have, but they're not worth the money.
21. I use automatic devices a lot just because I find them useful.
22. Autoland capability would definitely enhance safety.
23. I use automatic devices mainly because the company wants me to.
24. Cat II and Cat III operations would mean very little to our company.
25. I have serious concerns about the reliability of this new equipment.
26. I am worried about sudden failures of the new digital devices like the DFCS and the ARTS.
27. Automation reduces overall workload.
28. The new equipment is more reliable than the old.
29. Too much automation can be dangerous.
30. Overall, automation reduces pilot fatigue.
31. I think that the -80 is a significant step forward in short and medium haul aircraft.
32. The -80 is just another DC-9 with some new toys.
33. The ARTS feature of the -80 is a real plus for safety on takeoff.
34. Flying the -80 is definitely easier than flying the older models.
35. I enjoy flying the -80 more than the older DC-9s.
36. I like to use the new features of the -80 as much as possible.

questions regarding their experiences as instructor pilots on the -80. Of particular interest were questions dealing with their perceptions of problems encountered by students during training, and during their Initial Operating Experience (IOE) on the line.

It turned out that the interviews were even less structured than the author intended. He quickly discovered that it was difficult to keep the pilots from jumping from one subject to another. So the order of the questions were abandoned, and the only structure imposed was to make certain that all topics were covered, regardless of order. It is probably safe to say that the inability of the interviewer to keep the discussions running in a structured order could be taken as a measure of the enthusiasm that the pilots had for the project. Most came in showing advanced preparation for the interview, with an "agenda" of things they wanted to say about the automatic features and the cockpit design. Some arrived with a written list of items that they wished to cover, and several times, pilots who were not part of the study panel arrived and asked to be interviewed.

Data Handling

The Likert scales were scored by constructing a ruler which measured the position of the "X" mark in terms of its distance from the leftmost (strongest disagreement) point on the scale. The position of the "X" was scored from 01 (strongest disagreement) to 99 (strongest agreement). Scores close to 50 indicate mid-scale ("neither agree nor disagree") responses. Thus, for each pilot, there were 36 Likert scale scores ranging from 01 to 99, and on the same form, three questions regarding flying experience: total flying time, total time in the -80, and the number of days (at the time of filling out the forms) since last flying the -80. The results are summarized in Tables 2-A and 2-B in the next section.

The percent-use scale data was recorded in terms of percentages, from 0 to 100. Pilots were instructed to place an "X" in any cell where the equipment was not usable or its use invalid (e.g. autobrake at cruise), to distinguish that condition from legitimate responses of zero use. Questionnaires were returned by mail.

The data were entered by keyboard into an Apple II computer, using a commercially available database management package, DB Master, which created a file for each questionnaire form. For statistical analysis, the data were ported via telephone modem from the database in the Apple to the University of Miami's Univac 1108 mainframe. A more detailed writeup of the data management system can be found in Appendix 2.

Figure 1

DC-9-80 attitude questionnaire

1. Flying today is more challenging than ever.

1-----1-----1-----1-----1
Strongly Disagree Neither Agree Strongly
Disagree agree nor Agree
Disagree disagree

2. I miss the "good old days" of simpler aircraft.

1-----1-----1-----1-----1
Strongly Disagree Neither Agree Strongly
Disagree agree nor Agree
Disagree disagree

3. I am concerned about a possible loss of my flying skills with too much automation.

1-----1-----1-----1-----1
Strongly Disagree Neither Agree Strongly
Disagree agree nor Agree
Disagree disagree

4. I hand fly part of every trip to keep my skills up.

1-----1-----1-----1-----1
Strongly Disagree Neither Agree Strongly
Disagree agree nor Agree
Disagree disagree

5. Hand flying is the part of the trip that I enjoy the most.

1-----1-----1-----1-----1
Strongly Disagree Neither Agree Strongly
Disagree agree nor Agree
Disagree disagree

6. I think they've gone too far with automation.

1-----1-----1-----1-----1
Strongly Disagree Neither Agree Strongly
Disagree agree nor Agree
Disagree disagree

Figure 2

1/2 OF LEGS USED

SYSTEM OR FEATURE	T/O & CLIMB - FIRST SEGMENTS	TRANSITION & ENROUTE CLIMB	CRUISE	DESCENT	FINAL AFF & LANDING
AUTOTHROTTLE	:	:	:	:	:
THRUST COMPUTER INDICATOR	:	:	:	:	:
SFD/MACH CONTROL	:	:	:	:	:
ALTITUDE HOLD	:	:	:	:	:
VOR CAPTURE & TRACK	:	:	:	:	:
LOCALIZER CAPTURE & TRACK	:	:	:	:	:
GLIDESLOPE CAPTURE & TRACK	:	:	:	:	:
FLIGHT DIR. V-COMMAND BARS	:	:	:	:	:
SLOW/FAST COMMAND	:	:	:	:	:
ALTITUDE PRESELECT	:	:	:	:	:
AUTOBRAKE SYSTEM	:	:	:	:	:
HEADING SELECT	:	:	:	:	:
BANK ANGLE LIMITER	:	:	:	:	:
DIAL-A-FLAP	:	:	:	:	:
RAW DATA VIS. APP.-ILS R/W	:	:	:	:	:
F/D ON VIS. APP. - ILS R/W	:	:	:	:	:

IV. QUESTIONNAIRE RESULTS

Likert Attitude Scales

The Likert attitude scale statistics are summarized in Tables 2-A and 2-B. The samples sizes were 37 in Wave One and 20 in Wave Two, on some scales the samples sizes were less, due to missing data in the questionnaire forms. Appendix 4-A and 4-B contain in computer printout form the entire intercorrelation matrix for the 36 attitude items and the three flying time items (total of 39 points per pilot).

Since 36 attitude scales are more than a reader can digest, we have sorted the items by content into groupings, which are listed in Table 3 and displayed in Figures 3-A through 3-F. Note that this grouping was based on subjective judgements on the part of the author -- it does not represent the results of statistical clustering techniques such as factor analysis. There were too few data to use such methods, as they require that there be more respondents than items. The six groupings, subjective as they may be, make it easier to read and discuss the data. Figures 1-A through 1-F depict in graphic form the mean of the responses to the attitude questions plus and minus one standard deviation.

The striking feature of these data is the great diversity in attitudes, as seen both by the large standard deviations (about 15 to 20 points in most cases) as well as the ranges. On most items the range of opinions run full-scale -- from total disagreement (01) to total agreement (99). It is not usual for pilots to have diverse opinions about their jobs and equipment, but the magnitude of disagreement was somewhat larger than expected. Extremes of opinion will appear again in the face-to-face interviews to be discussed in the next two sections.

Frequency-of-Use

The data from the frequency-of-use form are summarized in Table 4-A and 4-B. Note that the sample size varies considerably throughout the -80 cells in this table, due to the fact that it was up to the respondent to decide whether or not the equipment feature was appropriate for the phases of flight.

Open-ended Questions

Five open-ended questions were included at the beginning of the questionnaire package. Responses to these are summarized in Tables 5-1 to 5-5.

Free-form Comments

Respondents were encouraged to write in any comments they wished to make, not necessarily in response to any particular question, and several did so. These are summarized in Table 6.

Table 2-A

Summary statistics on flying experience data and attitude scale responses. Refer to Table 1 for full text of Likert statements.

WAVE ONE

Item	N	Mean	S.D.	Min	Max
total time	37	15,244	7901	4415	30,850
time in -80	37	365	290	37	1,180
days since -80 flt	36	11	19	0	90
1. challenging	37	62	26	1	99
2. good old days	37	37	20	1	80
3. loss of skills	37	53	27	1	99
4. hand fly	37	53	27	1	99
5. enjoy hand fly	37	58	15	25	99
6. too far w/ auto	37	34	23	1	80
7. hand vs. auto	37	49	27	1	99
8. mod important	37	56	24	1	99
9. more automation	37	54	25	1	99
10. future auto	37	58	22	25	99
11. autothrottles	37	62	25	1	99
12. young vs. old	36	58	27	5	99
13. overuse of auto	37	59	23	1	99
14. manage flight	37	70	21	20	99
15. time problems	36	43	23	1	99
16. old resist	36	53	21	1	99
17. more to watch	36	38	24	1	99
18. auto profit	36	37	25	1	99
19. auto not help	36	36	22	1	99
20. not worth \$	36	48	25	1	99
21. auto is useful	36	68	17	25	99
22. autoland	37	48	23	1	99
23. company wants	37	43	22	1	95
24. cat II & III	37	47	27	1	99
25. reliability	37	45	25	1	99
26. sudden failures	37	47	28	1	99
27. less workload	37	66	23	1	99
28. new = reliable	37	61	25	1	99
29. too much auto	37	54	28	5	99
30. reduce fatigue	37	67	19	25	99
31. -80 = progress	37	80	13	50	99
32. -80 new toys	37	33	21	1	85
33. ARTS = safety	37	71	17	25	99
34. -80 easier	37	60	22	1	99
35. I enjoy -80	37	77	21	25	99
36. use features	37	70	18	25	99

Table 2-B

WAVE TWO

Item	N	Mean	S.D.	Min	Max
total time	20	13,891	8031	4500	28,000
time in -80	20	674	310	100	1,350
days since -80 flt	20	12	15	0	45
1. challenging	20	62	23	1	99
2. good old days	20	40	19	1	75
3. loss of skills	20	55	28	1	91
4. hand fly	20	60	26	12	99
5. enjoy hand fly	20	53	18	12	87
6. too far w/ auto	20	46	22	1	75
7. hand vs. auto	20	42	22	1	83
8. mod important	20	47	23	1	85
9. more automation	20	57	19	25	88
10. future auto	20	56	21	25	87
11. autothrottles	20	52	24	12	99
12. young vs. old	20	62	19	1	90
13. overuse of auto	20	60	22	25	99
14. manage flight	20	68	20	25	99
15. time problems	20	39	18	1	75
16. old resist	20	54	21	10	86
17. more to watch	20	44	24	1	75
18. auto profit	20	43	24	1	88
19. auto not help	20	36	14	10	60
20. not worth \$	20	44	22	1	99
21. auto is useful	19	69	17	30	99
22. autoland	19	49	17	10	75
23. company wants	20	49	21	25	75
24. cat II & III	20	42	19	25	85
25. reliability	20	40	21	5	75
26. sudden failures	20	44	23	5	75
27. less workload	20	70	13	40	90
28. new = reliable	20	60	15	30	85
29. too much auto	19	48	23	18	95
30. reduce fatigue	20	67	18	25	99
31. -80 = progress	20	81	12	65	99
32. -80 new toys	20	29	18	1	75
33. ARTS = safety	20	67	18	10	99
34. -80 easier	20	60	16	25	87
35. I enjoy -80	20	75	17	48	99
36. use features	20	72	16	33	99

Table 3

Graphic presentation of attitude scales

The following figures graphically depict the means and standard deviations of the 36 Likert scales for Wave One and Wave Two. The 36 scales are grouped by subject matter. The groupings are not by statistical clustering.

<u>Figure</u>	<u>Grouping</u>
3-A	General attitude toward automation and flying
3-B	Impact of automation on skills maintenance/erosion
3-C	Specific equipment capabilities; -80 in general
3-D	Pilot age and acceptance of automation
3-E	Equipment reliability and safety
3-F	Impact of automation on perceived workload, fatigue, motivation and cockpit management

For each scale, there is a pair of lines: the top line represents the data for Wave One, and the bottom line for Wave Two. The center of each line is the mean, and the length of the line in each direction from the center is one standard deviation. If the distribution of responses to the Likert scales were normally distributed, the length of the line should represent about 68% of the responses. See Table 2-A and 2-B for exact values.

Figure 3-A

A. General attitude toward automation and flying

1. Flying today is more challenging than ever.
2. I miss the "good old days" of simpler aircraft.
6. I think they've gone too far with automation.
7. I can fly the airplane as smoothly and safely by hand as with automation.
8. It is important to me to fly the most modern plane in the company's fleet.
9. I look favorably on automation in the cockpit -- the more the better.
10. I am looking forward to even more automation in future planes.
18. Automation is the thing that is going to turn this industry around and make it profitable again.
19. Automation may be helpful in long-haul operations, but not for short-segment operations like ours.
20. All these new features are nice to have, but they're not worth the money.
29. Too much automation can be dangerous.

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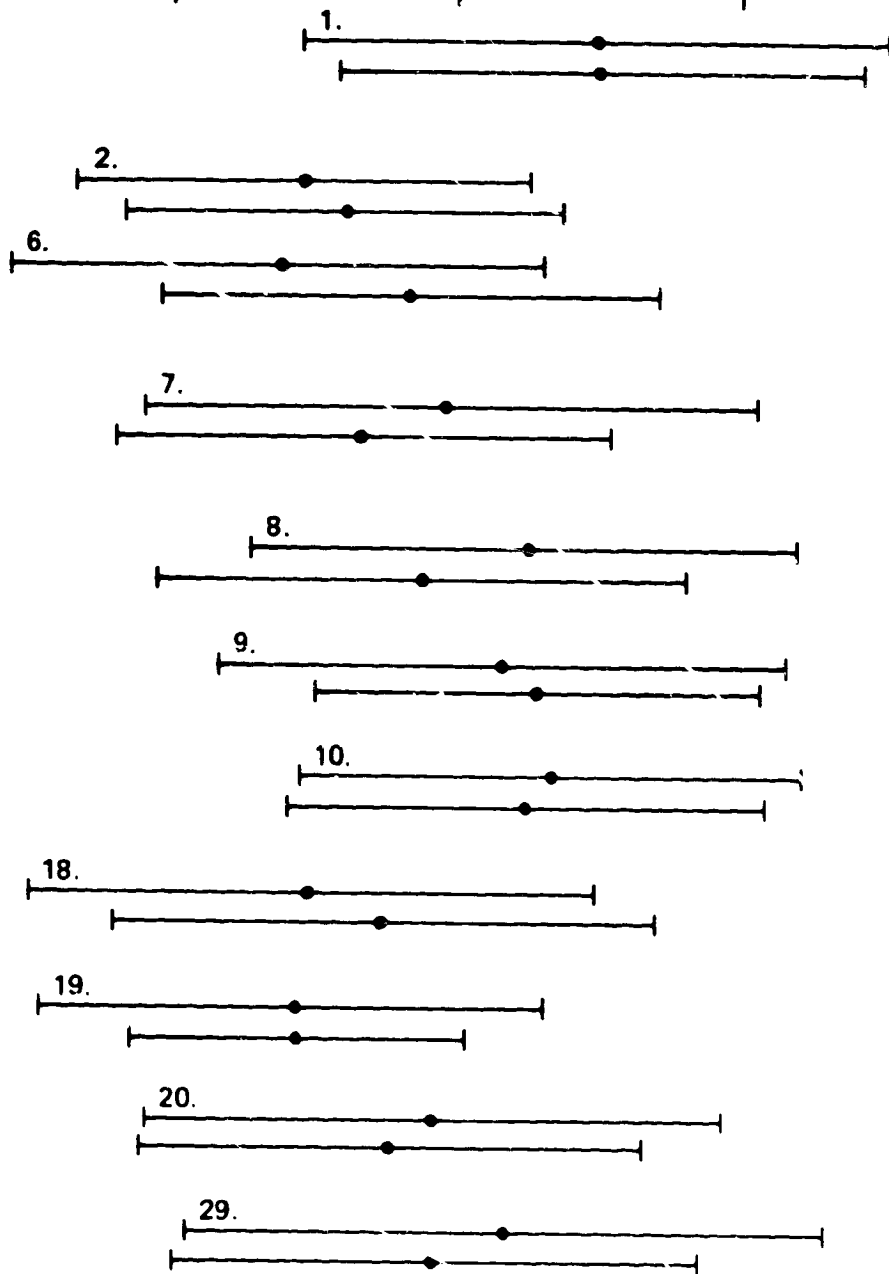


Figure 3-B

B. Impact of automation on skills maintenance vs. erosion

3. I am concerned about a possible loss of my flying skills with too much automation.
4. I hand fly part of every trip to keep my skills up.
5. Hand flying is the part of the trip I enjoy the most.
13. Pilots who overuse automation will see their flying skills suffer.

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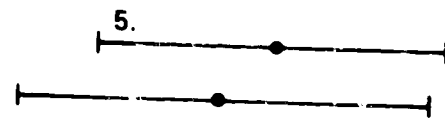
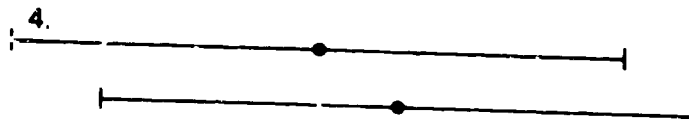
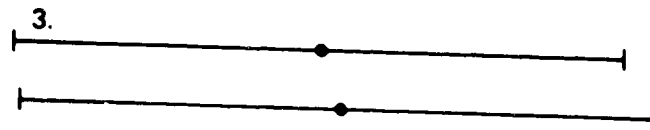


Figure 3-C

C. Specific equipment capabilities, and the -80 in general

11. I wish we had full autothrottle on the -10s, -30s, and -50s.
22. Autoland capability would definitely enhance safety.
24. Cat II and Cat III operations would mean very little to our company.
31. I think that the -80 is a significant step forward in short and medium haul aircraft.
32. The -80 is just another DC-9 with some new toys.
33. The ARTS feature of the -80 is a real plus for safety on takeoff.
34. Flying the -80 is definitely easier than flying the older models.
35. I enjoy flying the -80 more than the older DC-9s.
36. I like to use the new features of the -80 as much as possible.

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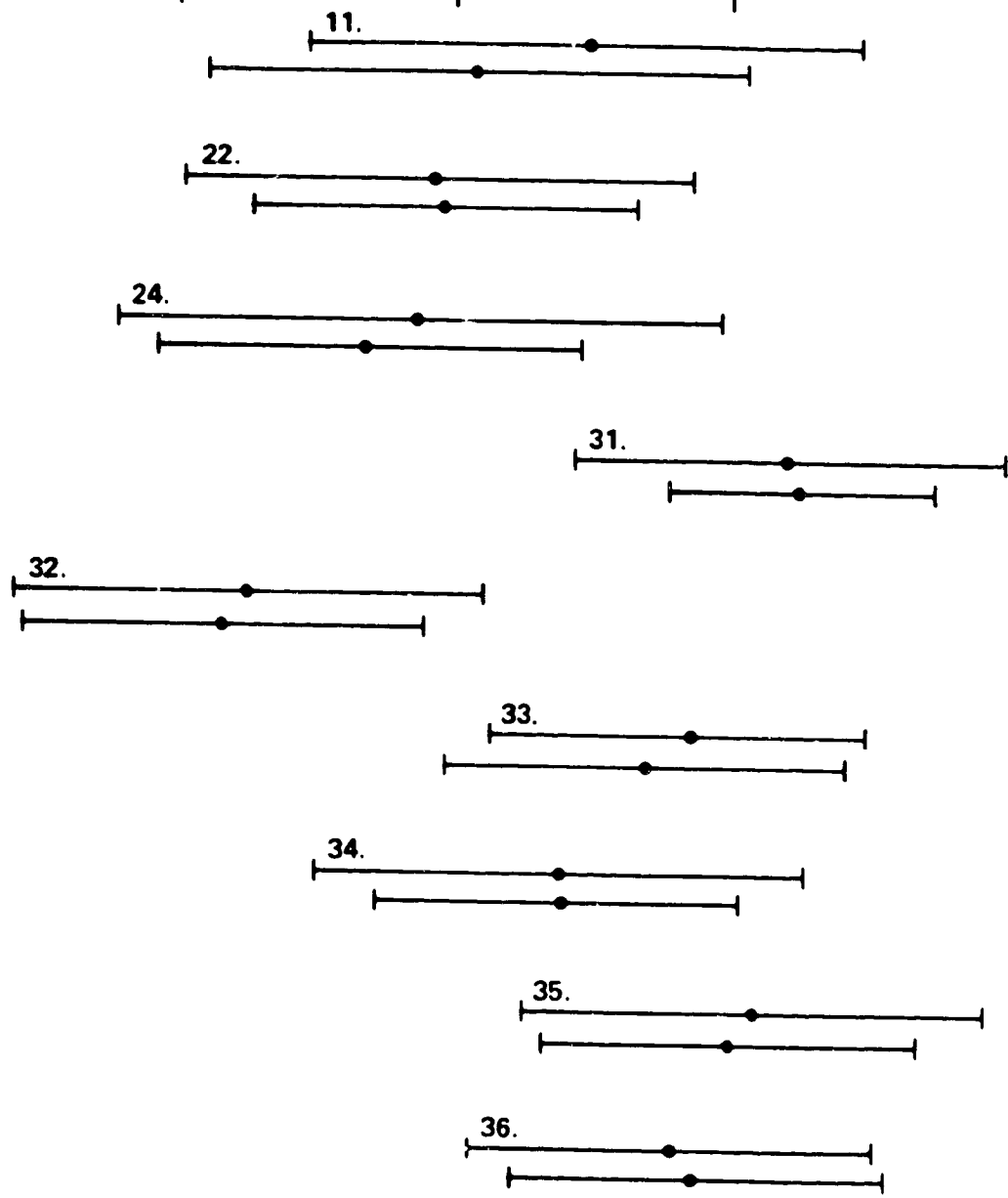


Figure 3-D

D. Pilot age and acceptance of automation

12. Younger pilots catch on to automation faster than older ones.
 16. Older pilots seem to resist the new technologies.
-

Figure 3-E

E. Equipment reliability and safety

25. I have serious concerns about the reliability of this new equipment.
26. I am worried about sudden failures of the new digital devices like the DFGS and the ARTS.
28. The new equipment is more reliable than the old.

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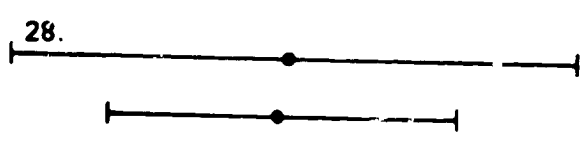
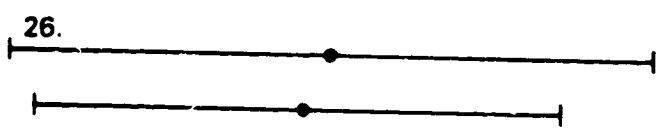
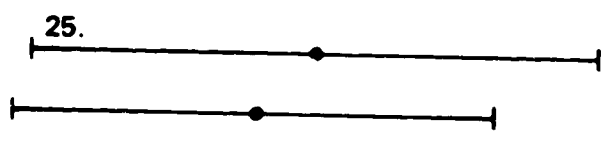
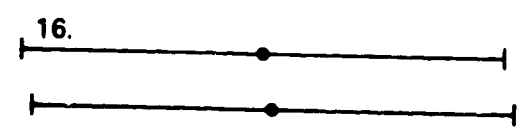
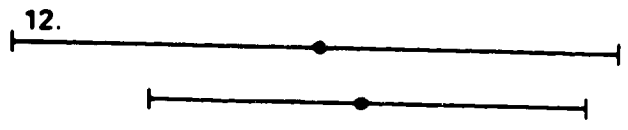


Figure 3-F

F. Impact of automation on perceived workload, fatigue, motivation, and cockpit management

14. Automation frees me of much of the routine, mechanical parts of flying so I can concentrate more on "managing" the flight.
15. I spend more time setting up and managing the automation (such as the DFGS) than I would hand flying or using old style autopilots.
17. Automation does not reduce workload, since there is more to keep watch over.
21. I use automatic devices a lot just because I find them useful.
23. I use automatic devices mainly because the company wants me to.
27. Automation reduces overall workload.
30. Overall, automation reduces pilot fatigue.



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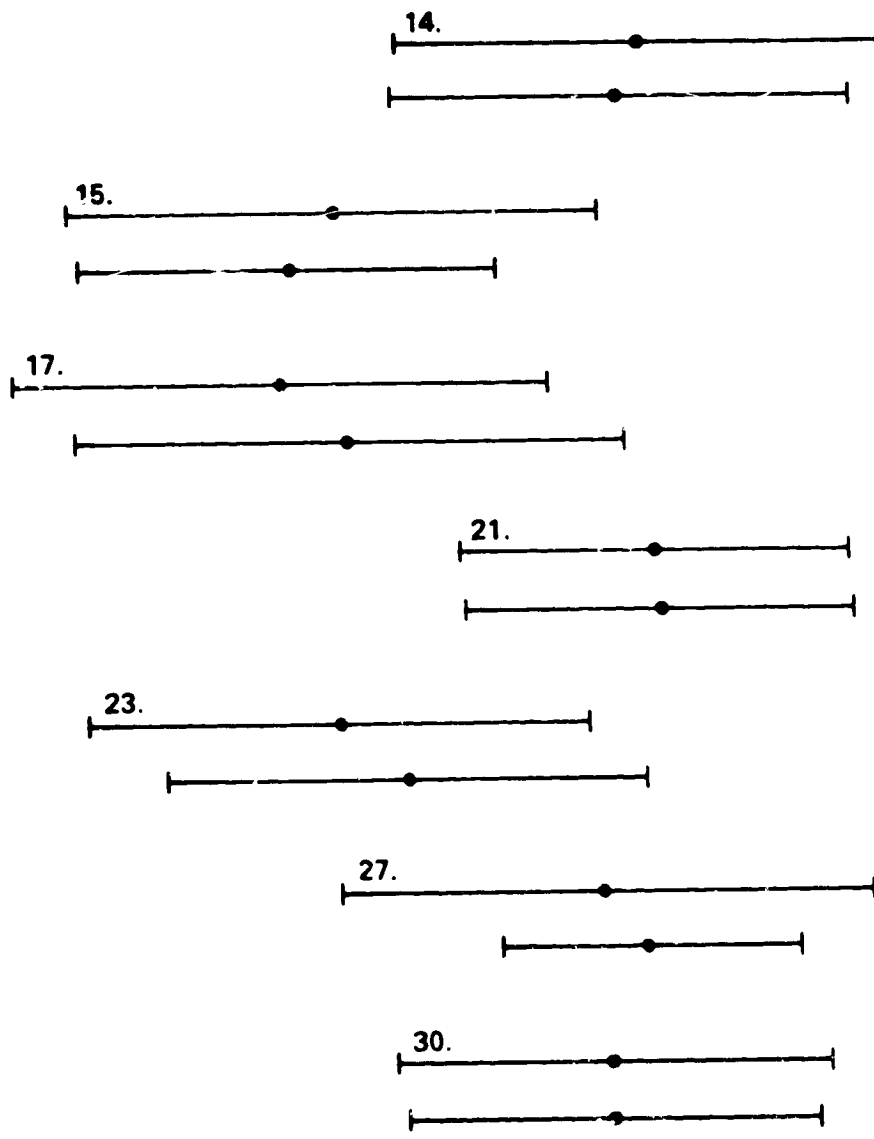


Table 4-A and 4-B

Frequency-of-use chart

Crew members were instructed to enter into each appropriate cell the per cent of legs on which they used each -80 feature, during five phases of flight. Thus the numerical values from 0 to 100 could be entered.

Some of the cells are by their nature invalid - e.g. autobrake at cruise. Crews were instructed to place an "X" in each invalid cell.

Examination of the data reveals that there was some confusion about this instruction, and in some places entries, particularly zeros, were placed in invalid cells. Thus, the reader should not take seriously the statistical values for cells with very small sample sizes. For example, three respondents entered a numerical value for the use of the dial-a-flap at cruise.

The data are expressed as follows:

Mean %	Standard Dev. %	(Sample size *)
--------	-----------------	-----------------

For example, the Wave One data for altitude hold at cruise reads:

94	23	(34)
----	----	------

meaning that the mean usage of the 34 pilots responding was 94% of the legs, with an S.D. of 23%.

* Number (out of total) responding with numerical value.

Table 4-1
Frequency of use - Wave One

SYSTEM OR FEATURE	T/O & CLIMB FIRST SEGMENTS	TRANSITION & ENROUTE CLIMB	CRUISE	DESCENT	FINAL APP. & LANDING
AUTOTHROTTLE	99 03 (37)	99 03 (37)	73 31 (37)	78 29 (37)	51 29 (36)
THRUST COMPUTER INDICATOR	99 01 (34)	99 01 (34)	83 31 (32)	75 42 (22)	82 38 (25)
SPD/MACH CONTROL	83 31 (36)	88 23 (37)	84 29 (34)	75 32 (37)	61 37 (36)
ALTITUDE HOLD	62 47 (22)	61 44 (26)	94 23 (34)	61 44 (24)	43 41 (20)
VOR CAPTURE AND TRACK	30 35 (30)	44 34 (37)	50 33 (36)	47 33 (36)	39 34 (27)
LDC CAPTURE AND TRACK	-----	-----	20 35 (08)	33 32 (23)	50 26 (37)
GLIDESLOPE CAPTURE & TRACK	-----	-----	28 44 (05)	25 28 (22)	47 29 (37)
F/D V-COMMAND BARS	92 20 (37)	65 42 (35)	58 44 (35)	59 44 (36)	67 33 (36)
FAST/SLOW COMMAND	44 43 (31)	17 03 (25)	15 31 (21)	13 30 (21)	44 38 (37)
ALTITUDE PRESELECT	99 05 (37)	99 02 (37)	97 18 (32)	98 06 (37)	75 37 (23)
AUTOBRAKE SYSTEM	-----	-----	-----	27 46 (03)	56 34 (37)
HEADING SELECT	79 28 (34)	90 18 (36)	76 28 (36)	83 20 (36)	55 34 (36)
BANK ANGLE LIMITER	94 19 (37)	91 24 (37)	93 23 (37)	93 20 (37)	81 30 (37)
DIAL-A-FLAP	80 20 (36)	25 30 (04)	33 58 (03)	40 55 (05)	33 50 (09)
RAW DATA ON VIS. APP. TO ILS	-----	-----	-----	28 26 (08)	40 31 (36)
F/D ON VIS. APP. TO ILS R/W	-----	-----	-----	79 159 (09)	41 34 (36)

Table 4-2

Frequency of use - Wave Two

SYSTEM OR FEATURE	T/O & CLIMB FIRST SEGMENTS	TRANSITION & ENROUTE CLIMB	CRUISE	DESCENT	FINAL APP. & LANDING
AUTOTHROTTLE	98 04 (20)	98 04 (20)	86 20 (20)	78 25 (20)	54 33 (20)
THRUST COMPUTER INDICATOR	99 01 (20)	99 02 (20)	86 30 (19)	75 43 (15)	84 33 (18)
SPD/MACH CONTROL	76 37 (18)	89 23 (19)	85 20 (20)	69 33 (20)	55 35 (20)
ALTITUDE HOLD	56 47 (10)	55 47 (10)	79 40 (19)	58 48 (11)	36 41 (11)
VOR CAPTURE AND TRACK	34 34 (16)	42 32 (19)	46 32 (20)	47 28 (19)	27 30 (16)
LDC CAPTURE AND TRACK	-----	-----	-----	26 20 (10)	50 27 (20)
GLIDESLOPE CAPTURE & TRACK	-----	-----	-----	19 25 (07)	45 31 (20)
F/D V-COMMAND BARS	94 12 (20)	67 44 (20)	65 45 (16)	61 44 (18)	61 31 (20)
FAST/SLOW COMMAND	43 41 (17)	07 09 (12)	03 07 (10)	03 07 (10)	54 40 (18)
ALTITUDE PRESELECT	99 03 (19)	99 02 (20)	99 01 (18)	99 03 (20)	56 34 (11)
AUTOBRAKE SYSTEM	-----	-----	-----	-----	63 26 (20)
HEADING SELECT	73 34 (19)	90 13 (20)	83 20 (20)	82 20 (20)	57 26 (18)
BANK ANGLE LIMITER	96 06 (20)	98 04 (20)	94 20 (20)	94 20 (20)	81 25 (19)
DIAL-A-FLAP	77 28 (20)	-----	-----	-----	-----
RAW DATA ON VIS. APP. TO IL6	-----	-----	-----	67 15 (03)	34 31 (19)
F/D ON VIS. APP. TO ILS R/M	-----	-----	-----	15 121 (02)	41 37 (19)

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Table 5-1 to 5-5
Open-ended questions

<u>Table</u>	<u>Question</u>
5-1	What feature or piece of equipment not presently in the -80 would you like to have installed?
5-2	Since flying the -80, have you seen any confusion or incorrect operation on the part of other crew members?
5-3	Are there any features or modes of the -80 that you are still not sure of or comfortable with?
5-4	What features were the hardest for you to learn? What do you think the problem was?
5-5	If you could make any changes in the cockpit layout, equipment or modes of the -80, what would you like to change?

Table 5-1

Question 1. What feature or piece of equipment not presently in the -80 would you like to have installed?

Equipment	Responses:	
	Wave	
	1	2
Performance data computer system (PDCS)	8	3
Long range navigation *	7	3
Groundspeed readout	5	3
None (stated as such - not blank)	2	2
Blank	2	3
Non-glare glass on all instruments	1	
Improved pressurization control	2	
Individual heading, airspeed controls for DFGS	2	2
Push-button entry for zero fuel weight	1	
Forward "blue room" (lavatory)	1	
Mirror to check wingtips	1	
Red light illuminating V-speed book	2	
Collision avoidance system	3	
Doppler radar	1	
Red instrument lights	1	1
Standby frequency on VORs	1	
Aural altitude alert	6	1
Head-up display	4	1
Wind shear detector	1	
More visible "caution" lights	1	
Faster cancelling of gear-up warning	1	
Stabilizer adjusting syste	1	
Pencil holder	1	1
Overhead hand hold to aid seat adjustment	1	
Improved light rheostats	1	
High frequency radio		1
Improved seats		1
Cat II capability		1
Total responses	57	23

* Includes RNAV, Omega, and INS

Table 5-2

Question 2. Since flying the -80, have you seen any confusion or incorrect operation on the part of other crew members? Please describe.

(The author has attempted where possible to preserve the exact language of the respondents. In some places, for clarity or compactness, the language is paraphrased. Replies simply yes/no are not included.)

WAVE ONE

a. Autopilot and flight guidance system in general
(6 respondents)

Rarely see errors. Only in new crew members. We are well standardized.

Turning the wrong knob, pushing the wrong button, deprogramming the DFGS and neutralizing it.

Minor errors in the DFGS setup.

b. Confusion between IAS and Mach hold and speed and Mach select
(6 respondents)

Some pilots don't seem to realize that these are distinct features.

Confusion as to what the speed select and Mach select buttons will do to A/T and pitch command as opposed to IAS hold and Mach hold.

New F/Os not sure which mode to use.

Spd/Mach control usage at intermediate altitudes - esp. low lim.

c. Autothrottle system management (8 respondents)

Managing the ATS, especially going from climb EPR to cruise with a low level off - e.g. 'level at 3000, maintain .170'.

Clamping ATS when they didn't mean to

Excessive use of ATS at low altitude

Initially confusion on how to maintain throttles at idle descent

Waiting for power to come on in descent

Use of spd select during idle descent on profiles

Spd sel knob hard to operate in fast slew position

d. A/P and A/T interaction (5 respondents)

"It's hard to program A/P and A/T fast enough to keep up with ATC, so we uncouple and fly by hand."

Confusion about overlapping functions of the A/T and A/P and improper interpretation of the FMA before mode selection.

Unfamiliarity and incorrect use of A/P and A/T for takeoff, climb and descent.

"Most incorrect operations center around the use of the A/T and A/P speed control, resulting in a CLAMP indication on the FMA."

e. System operation in general (6 respondents)

"It takes two months of line flying, about 150 hours, to understand all the systems."

"Not always in proper T/O mode when we begin T/O - mode confusion."

Controls are more sensitive - hdg knob, alt select...it takes a lot of time and experience.

"Reaching to wrong positions for switches and radios - it's different from other DC-9s."

f. Other comments

Forgot to select speed/Mach selector for cruise speed. Same comment after descending to new altitude.

Pilots not arming altitude alerter.

"Flap retraction time, and turn with altitude restriction,

forgetting to reprogram, so I'll snap off A/P and A/T and hand fly." *

Difficulty in operating flap handle after dial-a-flap T/O.
(2 respondents)

Confusion over which function to use, like SPD SEL or CL-EPR.

Hard to set up DFGS for back-course ILS

Flap/slat retract systems

* Not clear what is meant by reference to flap retraction time.

WAVE TWO

a. Autopilot and flight guidance system in general
(6 respondents)

Having A/P disengage for no reason causes real confusion, esp. on IFR approaches

Forgetting to put in new altitude to capture

Moving pitch wheel when capture has started

Forgot to set assigned altitude and forgot to push Mach and A/S on A/T control

Turning the wrong knobs, like course instead of hdg

In leveloff, tendency not to let the A/P do it for you - reverting back to earlier aircraft

b. Confusion between IAS and Mach hold. and speed and Mach select (none)

c. Autothrottle system management (7 respondents)

Management of ATS and speed selector in general (3)

A/S knob clumsy to turn

ATS surging and clamp mode

ATS is area of confusion during a busy approach when things start to happen

d. A/P and A/T interaction

"Confusing" (2)

e. System operation in general (6 respondents)

Pushing the wrong button (Spd/M) (2) Spd/M and hdg knobs too similar in feel, and sometimes have the same numbers (e.g. 210 mag hdg. and airspeed). Captains manipulate the wrong one often.

Grabbing the wrong knob on the DFGS

Misreading the A/S bug for the V-ref (white) bug

Having to reset dial-a-flap because setting (detent) can't be found with flap handle

"Most of us have been in the -80 for quite a while, and most of the incorrect procedures are just a matter of getting in a hurry and not thinking"

f. Other comments

Forgetting to put in the new ZFW

Forgetting to slew the heading bug before T/O

Not checking the FMA when making a speed, heading, or altitude change (2)

Table 5-3

Question 3. Are there any features or modes of the -80 that you are still not sure about or comfortable with?

(-80 flying time of respondent to the closest 50 hours is included in parentheses)

WAVE ONE

No (800, 100, 500, 750, 400, 150, 550, 600, 1000, 1200, 800, 150, 100, 50, 200, 400, 100, 300, 450)

"No, but company should be more specific on how descents should be made -- Mach hold, speed select, or clamp. Standardization is the key to a good flight." (800)

"No, except that the plane is so automated that my last 6-month check was not exactly perfect." (600)

"I'm not sure why, after cruising at M.76, when you push in speed/Mach set knob, it reverts back to Mach after displaying airspeed. You then have to push speed select to keep the speed you want." (150)

"I'm not ever comfortable with the A/P to intercept a LOC/GS course. I can do it so much smoother and almost immediately establish a decent wind correction crab. Then I'll engage the ILS/TRK feature." (300)

"Alert arm feature sometime disarms itself. A/T lags behind speed selected and then over-controls to get speed back. A/T oscillates excessively in cruise." (400) (See footnote, p. 87)

"I'm still new and my -80 time has been spread over a long period. Conflict with A/T and A/P and some nomenclature (confusing). Also IAS/Mach hold." (50)

"Speed/Mach selector does not always change to correct mode."

"Upon engaging the A/P after takeoff, about 70% of time there is a disagreement between A/C trim and A/P logic, with resulting uncomfortable pitch changes. I haven't been able to determine if I fail or the system does." (100)

"A change in clearance within 20 miles of an airport seems to increase my workload at my experience level." (50)

ATS (50, 200)

"-80 doesn't descend like other DC-9s. A/Ts often spool engines when not wanted (often not noticed at night) when trying to descend. End up high and fast on approaches, so you have to plan further ahead with cushion." (150)

Turbulence mode -- haven't needed it yet (400)

A/Ts on idle power descents come up when I think they shouldn't (150)

Still don't understand the ATS. I disconnect them for descent and reconnect for final approach (400)

Use of DFGS on back-course ILS (400)

"Altitude hold -- I've seen A/C leave captured altitude four times. Each time the alt sel knob had slipped into the next detent, higher or lower" (200)

WAVE TWO

No (400, 800, 1350, 350, 600, 900, 1150, 1200, 800, 700, 600, 700, 600, 700, 400, 800)

Alt capture and approach capture and track on A/P (400)

Using dial-a-flap settings (400)

LOC-only approach -- push VOR-LOC for capture; push ILS and it will still capture (100)

Autoland and auto G/A (350)

A/Ts sometimes clamp at wrong T/O EPR (600)

VOR capture and track mode not very smooth for the money (600)

Table 5-4

Question 4. What features were the hardest for you to learn?

Question 4(a) What do you think the problem was?

(Flying time in -80 to closest 50 hours in parentheses)

WAVE ONE

A/T and speed/Mach and its relationship to pitch (800, 150)
A/T. At time instructors weren't sure how it worked (150)
A/T. Reverting to Lo Lim after being retarded (150, 150)
A/T. Not enough instruction (150)
A/T in general (50, 150, 150, 200); Integration of computer into
specific modes (50); Inadequate training for modes (150)
A/T smoothness -- trying to cope with built in problem (200)

All systems fairly easy; no difficulty (300, 1200, 600, 50)

Remembering to put proper flap setting into CG computer and
stowing the flap detent on climb checklist. Rushing to get
everything done between the time when I get weight tab and engine
start (300)

DFGS (500, 800, 400, 100, 400). Lack of experience. Easy to
learn, just more to learn than anything else. "I'm not used to
computers." Way it was presented in ground school. Lack of a
simulator. No simulator, just a static airplane

Getting used to quiet cockpits after flying -10s (750)

A/T - A/P relationship (600, 150, 50, 550, 100, 400, 400)

Lack of experience - I fly -30 a lot (2 respondents).

Extreme number of possibilities with new features, and
company's insistence on using them all most of the time.

Some nomenclature doesn't help.

I think the two systems (A/P and A/T) should be taught
separately, then combined.

Different ways to make a proper descent. (800)

Descents are the only "zone of confusion."

Speed/Mach selector. What you get when you push in on the button, depending on what mode you are operating in, seems confusing. Confusing part is keeping in mind what mode you are in. (400)

Selecting proper mode and checking TARP * (400)

Adjusting to female voice on CAWS. Male voice would be better - I tend not to listen to women. (500) **

Sequencing the DFGS to produce desired effect. (1000)

New abbreviations - e.g. FMA *. Nothing to relate these to. (100)

Interactions and priorities of systems. You must fly the equipment to find best way to put it together. (50)

SPD SEL vs. IAS hold - continuous reduction of speed bug to maintain unspooled condition. Difficulty with different modes, but this was corrected with experience (150)

Checking the FMA (200)

Touching vert spd wheel disconnects ILS (100)

Use of hdg sel in flying VFR approaches. Too much time with head in cockpit. I'm used to DC-9 turn knob - can vary bank angle without looking in cockpit.

None (1200, 600)

* Flight mode annunciator (see Glossary, Appendix 3).

** Not clear whether this is facetious or serious comment. In interviews many pilots objected to the CAWS, but not specifically to female aspect of voice warnings. All but three of the warnings are female voices.

WAVE TWO

None (so stated) (1350, 1150, 800)

I fly the -80 on reserve. There's no continuity in operating it. I can fly the -80 only twice a month - it screws up learning and habit patterns. (400)

Insufficient training - no simulator (700)

Control during descent (400)

Separating A/T and A/P functions in my mind due to previous habits (350)

Habit interference from -50 (350)

Making smooth descent and landing - lack of experience (800)

Interrelation of A/T modes and speed functions. Poor instruction from the factory in relationships (600)

A/T in general; lack of training (700)

A/T functions too complex (100)

A/T, Spd/M and A/P control; lack of proper ground school preparation (400)

FMA - learning all the modes and learning to watch it (600)

ATS in descent - hard to get slowed down, esp. if you stay high for fuel conservation and ATC gives you a speed restriction in descent (900)

ATS in descent - lack of experience. Descent and approach phase are more difficult with this system (700)

Connecting A/P smoothly so soon after T/O; rate of climb between A/C and A/P are not in sync (1200)

Separating A/P and F/D in my mind; pushing IAS on A/P when I should have pushed F/D; the problem was me (600)

Table 5-5

Question 5. If you could make any changes in the cockpit layout, equipment or modes of the -80, what would you like to change?

WAVE ONE

Nothing (so stated - not blank) (8 respondents)

Left blank (3 respondents)

Aural "speed brake" warning (on touchdown) removed.

Presently if the DFGC goes off, we lose altitude capture. Change so that anytime A/P is coupled, we would have alt capture.

Individualize DFGS, A/S, and heading bugs. Make it possible to program hundreds of feet (it's hard to push knob and twist). Also for A/S and heading you have to look in two places, the instrument itself and the DFGS (to set bugs).

Cockpit lighting. (8)

In summary, complaints about the white lighting, and necessity to turn up floods to see the V-speed card. Recommendations for red light over the V-speed card. Several recommended lighting be like older DC-9s.

Better way to prevent accidental tail cone deployment.

Ground-speed readout should be added.

"Desensitize" A/T at cruise.

Have VOR accept drift correction that has been established.

Backlight following switches: IAS hold, Mach hold, EPR lim, Mach sel, VOR/LOC, ILS.

Button to silence CAWS. (2) One suggests mounting it on control wheel, and eliminating 80% of CAWS alerts.

Seats are uncomfortable (2)

Interference when ATC gives a change and capt. reaches for alt knob as F/O reaches for ppiitch wheel.

Comparator between the two A/P computers. If one goes bad,

both are inoperative and you have no A/P. Should be a way to override them or separate them so the good one can be used.

Amber light on radar altimeter too bright, esp. with voice warning of "minimums." Seen as "distracting and unsafe."

Get rid of ATS

Make pressurization more automatic -- like Boeing (727-200)

Location of wing light switches, and other external light switches. Nose light switch is mounted slightly higher than the wing light switches. Makes it appear that landing lights are in mid or extended position. Not so on older models of DC-9 - they were aligned.

Two heading knobs and two pitch wheels to keep from getting in each other's way.

Change speed knob to have different feel from course knob (2). Better speed knob (1)

Suppress voice warning system on ground.

Altitude alert - takes too long to select the 100-foot levels.

Remove ALFA speed on A/Ts.

Old style (dial and pointer) fuel gauges (in place of digital).

Change trigger point for gear warning from 210 knots (presumably to lower speed).

Eliminate undesired engine rpm increase when gear is lowered.

Move descent wheel (vert spd) and turn knob to center console.

CAWS warnings too "piercing" -- make more subtle and less repetitious.

Update flight and performance instruments and displays to more modern, easily-read, like C-141 tape instruments.

More reliable air data computer

Go to -50 A/P with spd/M hold.

WAVE TWO

None (so stated)

Blank (2)

Move green oxygen bottle to corner

Relocate turn knob to center pedestal

Cockpit lighting: general (2); red lighting on V-speed cards (7)

Change feel of knobs for A/S and course (make distinguishable)

Put in 20 degree flap notch so you don't have to dial it (2)

Relocate TCI * on the pedestal behind the throttles with annunciator in the same place

Change gear warning to 180 kts

Relocate pitch and roll modes of A/P to center pedestal

Functions related to each pilot's task should be assigned to his side of the cockpit

Add a minimum fuel warning

Vibration monitor more centrally located

Give each pilot his own hdg and spd controls

Make it easier for F/O to load the correct ZFW -- has to reach to captain's panel and twist knob

Change A/S bugs so DFGS and V-ref are not confused so easily

Flap/slat handle should be as easy to move as other DC-9s

Add groundspeed readout

Eliminate unnecessary CAWS warnings -- like landing gear above 5000 feet and spoiler deployed on ground

Make it like a -50; eliminate all the training and cockpit confusion. We made it a separate status, proving that pilots find it tough to go back and forth.

* Thrust Computer Indicator (see Glossary, Appendix 3).

Difficult to select TCI -- esp. at low altitude, critical times
of flight

A/S speed bug should be visible under all conditions

Smoother operating A/Ts

Table 6

The following comments were written on the Wave One questionnaire forms, in response to no particular question.

1. I have been flying from MSP to PHX to SNA. The weather has been very good most of the time, so we have not made any ILS approaches. When the weather is bad coming into MSP, we mostly use the autopilot coupled with ILS. It works very well. I have never used the flight director very much on any airplane, so I can't use it much now. However, I use it 100% for takeoff. I think the autopilot-autothrottle combination works very well. However, I must use it regularly, or I will get rusty with it. Also my instrument flying ability has gone down hill. Flying the -80 you are really only a computer programmer. I now have decided to fly the -80 one month and the -30 one month, rotating back and forth. If the company wants us to fly the -80 all the time, they should give us who want it a couple of hours per month in a -30 simulator to keep our instrument flying proficiency up.*

2. My most difficult task is a high VFR approach to an airport that requires rapid changes in airspeed, configuration and pitch. In this case I can do a smoother job hand flying. I don't have the eye-hand judgement coordination down yet when using the DFGS. Also, if the station used in VOR Nav is oscillating, I fly heading select because it's smoother.

The -80 is paradoxical. To be effective, safe and smooth with the automation, you must use it as much as possible. However, I am afraid I will lose touch with my manual flying skills if I don't fly it manually as well. I feel pilots flying the -80 should only fly the -80. The programming of the DFGS requires too much time with eyes in the cockpit if you don't fly it regularly. I feel that once you become skilled in programming the DFGS, you can keep your eyes outside more and it will be safer. Overall, I think the -80 is the neatest thing since night baseball.

3. TRI (Thrust Rating Indicator) - there is no specific setting for descent. It will remain at CRS (cruise) until set to GA (go-around) during the in-range check.

Speed/Mach Control - It is my policy to have the internal bug set (by using this control) at my target IAS/Mach regardless of the use of the autothrottle.

* This problem was largely resolved by the introduction of the "separate status" agreement. See p. 96, paragraph 10.

VOR/LOC Capture - Used very little since the equipment is much too sensitive relative to the quality of the nav aids. The A/C is much too "jerky" on the Loc and "sloppy" on VORs. If these inadequacies were corrected, I would use the capability from 75% to 100%.

Autobrake - I only use about 25% of the time - short runways, and high gross weight. I normally don't manually employ the brakes until below 80 knots.

4. I find that I am so busy with the automated portion of the aircraft that I am not looking outside the cockpit. I feel, however, that as I get more proficient, this will change. A few hours in a simulator with a good instructor could have made by transition much easier.

V. CHECK AIRMAN INTERVIEWS

DC-9-80 check airmen were interviewed in Minneapolis and Las Vegas. The intent of the interviews was to explore the experiences and difficulties, if any, encountered by the newly transitioning -80 pilots. In many instances it was difficult to separate this question from the check airman's own perception of the airplane. The comments are summarized below by general topic areas. In some places these are direct quotations, in others paraphrasing. Since check airmen were interviewed separately from line pilots, no distinction is made here between first and second wave interviews. These interviews occurred throughout the study, due to the fact that new crews were being trained at the two -80 domiciles at various times. Most check airmen interviews were performed early in the first waves at MSP and LAS in order to probe opinions during initial checkout and training of the -80 pilots.

Overall evaluation

New pilots tend to get behind - head in the cockpit. The FMA is new and they don't understand the modes. It takes one trip just to get the SPD/Mach control straight, and longer to master the FMA.

It's a new environment and people don't realize how different it is, especially when things go wrong. Lot of pilots think of it as an old plane with some new systems. But it's heavier, faster, and longer. Things go faster. The biggest problem is getting the three systems (F/D, A/P, and A/T) working together - it takes longer than I would have thought. It takes a month just to be able to operate it. The secret is scanning the FMA.

"Overall, the system is 'stable' since you can always push the yellow button (A/P disconnect) and turn it back into a DC-9."

Questions the dollar value and wishes the company hadn't bought it. Likes the fact that the heading bug can be set from either side. Otherwise prefers the -50 avionics.

In Initial Operating Experience (IOE), pilots had head in the cockpit too much.

Attitude and resistance

Tendency of new pilots to "give up." "If a problem arises (e.g. computer failure), neophytes will give up instead of trying to solve the problem. A simulator would help 100%." Sees some resistance to new features, especially on first trip. Some see cockpit as "too complicated" at first, but when they master it would prefer to fly the -80 over other models.

Saw some initial resistance. Some said they would prefer that -80 just be a new DC-9 with 217 engines, and no new features.

Pilots didn't like ground school - called it computer programming. Sees three distinct phases of attitude toward the -80 on part of newcomers:

1. "It's just another DC-9"
2. "It's neat - it's fun to fly"
3. "It doesn't work" - skepticism about the reliability

"Complacency would be the big problem if the stuff worked. It's a good thing that automation does not work all the time."

Reliability/Confidence in the plane

Complaints about the 904 flight guidance computer. Two check airmen reported that with bank angle limiter set to 30 degrees, the plane would bank 45 degrees, and attributed it to the 904.

Unreliability of the equipment is the biggest problem. * Several pilots mentioned the problem (also attributed to the 904) that if both Nav receivers were not set to the same ILS frequency, the plane would fly through the localizer without a capture maneuver. Also mentioned were brief interruptions of the computer, and the fact that when power was restored, it might revert to an earlier mode.

"Have seen it (altitude hold) disconnect and leave an altitude - we didn't catch it till the 250 (actually 300) foot alarm went off."*

Criticism of A/T at cruise, especially in mountainous terrain. "Doesn't do as well as the -50 in IAS and Mach hold."

Skill acquisition/loss and training

-80 students in transition feel that they lose manual skills and suffer when they have to take a 6-month check in a -30 simulator. Hasn't seen any sign of skill loss. Gave a -30 simulator check to a pilot who had flown only a -80 for a year, and he had no problem.

Pilots talk about "loss of scan," but I don't worry about it. There is no skill loss as long as I hand fly some. His practice is to hand fly below 10,000 feet on every third leg, and fly a -50 trip occasionally. Doesn't see any difference in the way he flies the 50.

* See footnote, p. 85.

Doesn't see any problem. Use everything that is there, and hand fly occasionally.

Most pilots like to do some hand flying. All should be made to. Check airman flies an entire leg by hand, but admits that it is less economical -- that A/P and A/T combination can fly the leg more economically. "My scan pattern would be zero if I used it (automation) all the time."

There is "major confusion" between the A/P and the A/T, e.g. CLMP annunciation. LAS pilots didn't fly the -50, so they did not have much experience with Mach hold and IAS hold. Former Boeing pilots did better in transition. Problem was which mode to use to hold airspeed.

At SNA, new pilots didn't know how to pull the power back at 1000' (for noise abatement cutback).

Secret to flying the -80 is "do what it take to give a smooth ride and reduce workload. Don't get 'stereotyped.' Use automation when appropriate."

The basic problem in school was "bits and pieces" - e.g. the A/P, A/T, and F/D. But the plane is one package, and this should be emphasized in school. *

Pilots should ride the jumpseat before going to school.

It takes 50 to 100 hours to be comfortable. Out-the-window time in the -80 is about half what it was in the -30. We're too busy inside.

The problems are consistent. At about 10,000' we get behind and high. The "whiz wheel" (hand-held vertical descent computer) prevents this.

On a coupled approach, trainee hit the wrong button - VOR/LOC instead of ILS. You need to learn to "preprogram", especially the speed bug. Complains of "fixation on digital displays." He puts tape over speed and heading window on DFGS to force trainees to look at the bugs. On older DC-9s, the control and the information was in the same place.

* See Page 96, paragraph 11.

Workload, fatigue, and "out-the-window" time

One pilot sees little difference between the -80 and earlier models in this respect, but the others stated that workload is less and fatigue less, once pilots become familiar

with systems and procedures. Two stated that the -80 allows more time for out-the-window scan.

"After a couple of months, an -80 is easier to fly. I could fly it longer (than -50) and feel less fatigue."

"There is less fatigue if the systems work as designed. If you keep up with the plane, the -80 allows more out-the-window time."

One check airman expressed belief that there is more requirement for monitoring activity in the -80, but another who mentioned monitoring said it was no different than the -50, which also demanded a lot of monitoring.

Initially there is more workload, then less. But if you include monitoring, there is no difference in total workload. In a terminal area, you spend a lot of time monitoring and use your hands a lot, so workload may increase.

Specific features - the Central Aural Warning System (CAWS)*

Likes the CAWS and the voice warnings, but would also like to have the aural tone ("beep") restored to the altitude alerter (for 750 feet prior to selected altitude).

"Overkill - the aural alerts are by biggest complaint about the 80." It is distracting at critical times. E.g., you're high and slow down (below 210 knots) and get "landing gear," and it's too loud. "Speed brake" (after touchdown) is annoying. "Stabilizer in motion" is not needed. T/O configuration warnings are too critical - should have high tolerances (see next comment).

Concern for the "cry wolf" problem (excessive false alarms). But generally likes the idea of voice warnings, especially for T/O configuration errors (see above). Some warnings are annoying and distracting - e.g. "Speed brake" after touchdown. Complains that "stabilizer in motion" does not always annunciate on ground check. "When a computer says something, it should be real." **

"As long as I can turn it off, it's OK."

Objection of gear-up warning speed (210 kts.). It should be 180.

* In interviews with check airmen and line pilots, comments about GPWS voice warnings were often included along with comments on the CAWS. The GPWS is a separate system, but the two are often seen as one since they both give voice annunciations.

** Most of these "false alarms" were associated with early models of the DFGC, and were corrected in later models.

Would like to mute some voice warnings, and set higher (less critical) trigger points on others, e.g. stabilizer in motion.

Make master caution light brighter.

Restore tone for 1000' before preselected altitude.

"CAWS is overdone. 'Speed brake' on landing is unnecessary. It can be heard in the cabin." *

Other specific devices

Doesn't like radar altimeter - requires too many turns to set. Doesn't like voice "minimums" alert.

In a rapid descent, with a crossing restriction, the A/P trim lags behind, the light comes on, possibly no capture.

A/P is too sensitive in pitch control - in turns as well as straight and level. Needs to be damped.

Likes coupled approach especially for a low-low approach, but for less demanding approaches, prefers to fly with F/D. On visual approach likes to use A/P and spend time looking out the window. On the 50, he hand flew visual approaches.

Confusion between A/T and A/P functions. "The plane is not a - 30. If you fly it like one, you'll be high and late."

Pilots forget bank angle limiter and leave it at 15 degrees. It should be at 10 degrees above 180 kts.

Several mentions of killing the altitude capture by moving the vertical speed knob.

Flap handle is a problem for the F/O...difficult to seat.

Vertical speed knob is awkward, esp. in turbulence.

The symbol (on HSI) for the course selector (+) is also on the knob, but the heading (triangle) is an "H" on the knob. Speed symbol (red triangle) is also the same.

Dial-a-flap and CG trim readout and indicators have opposite indications (numbers increase in opposite directions).

Objects to vertical speed wheel on glareshield instead of center console.

* Corrected in the 907 DFGC, approximately February 1985.

What additional equipment would you like to see?

Area navigation (specifically mentioned Omega) (2 respondents)

Head-up display (HUD)

Collision avoidance system (CAS)

Aural tone on altitude alerter (1000' before altitude)

VI. LINE PILOT INTERVIEWS

WAVE ONE INTERVIEWS

Why did you bid the DC-9-80?

It's the future of the fleet - I got the jump on others, since it was during summertime.

New equipment - "intriguing." (5 respondents)

New plane - advanced guidance system - "a neat DC-9."

Would have been forced to due to (lack of) seniority.

Enjoy the systems. I read up on it and passed up a bid on the Boeing (727) to wait for the -80.

Good trips for commuters.

Talked to pilots who have flown it.

I alternate between captain on a Convair (580) and a F/O on the DC-9. I like the -80 over other DC-9s. It's the future generation -- closer to the 757/767.

New plane and new technology. More options for bidding trips.

I'm low on seniority list - on -80 can avoid poor trips. Also I prefer new planes.

New sophisticated equipment. I bid it with only 2.5 years to retirement.

Forced bid. Like the trips - higher utilization (more hard time).

Didn't know much about automation. Never thrilled with the Boeing, so withdrew a Boeing bid to bid the 80. I like McDonnell-Douglas' approach to systems.

Advanced aircraft. Didn't see the Boeing as an advance.

New plane, new features, more engine power.

General comments about the -80 and automation

Like the plane - good on fuel efficiency. Will like it more when I learn the FMA better.

With rapid ATC changes, difficult to reprogram rapidly. (2) "In hand flying, the programming is done in your head."

Would have preferred to upgrade old fleet, e.g. strobe lights

Would like to see more separation between the knobs (DFGS). They should be shape coded.

More difficult when you get last minute instructions (ATC) - e.g. to land on 19 instead of 25 at LAS.

Like the flexibility of the options - wish I knew more about them.

At first I was always behind. With rapid ATC changes I would click it off. Now I use automation all I can. First month is rough - more planning is needed due to faster climb rate. Glad I didn't have to go back and forth to older models. I've been in the right seat 13 years, and this has me fired up again.

On 80, when I hand fly, I feel that I'm out on the end of a long pole (reference to length of fuselage and handling characteristics).

I like automatic systems when they work properly. Took less than a month to get comfortable...four trips SNA-PHX (four legs). It's clean, so you must plan descents earlier. Programming is complicated.

Not enthusiastic about automation. Wish the company had bought an -80 with the new engines, but configured like 50. (2)

Backlighting pushbutton switches on DFGS would help avoid confusion over modes. (3)

Not completely at home yet. Today I had a G/A (go-around) at SNA due to small plane traffic. Due to complexity, I clicked it off. Over the years I haven't flown a plane with auto G/A so I flew the way I knew how.

Ground school instructor at LGB was confused, esp. over DFGS. Still things I don't know. Instructors should have told us it is the same as the 50, the big difference being the A/T. Terminology is new (e.g. CLMP). CSS was a good tool.

Early difficulty - "which do I push now?" After two months, felt at home. CSS (cockpit systems simulator) helped teach how to set up approach.

Even hand flying the -80 is easier (than other DC-9s) - it's more stable. I've hand flown all the way from MSP to PHX.

Not all that different - it's still a DC-9. But I can fly it smoother. Heading bug and bank angle limiter much smoother on 80.

Reliability no problem in general. I have had ILS fail to capture. Flies too far, then tries to turn back and never gets to track.

Less stable on final - since it's cleaner. Have to start dirtying plane earlier. Hard to slow it down near runway.

I had trouble breaking habit of going to the HSI for the heading bug. Also got the wrong knob on the DFGS -- speed instead of heading.

General concern about reliability of automatics. (2)

What do you like about the plane?

Smoother powerback

Checklist almost same as -50

Quieter cockpit (3)

Not having to do uplatch check (landing gear) (2)

A/T is labor saving (2). Less time managing power, esp. in climb

A/S hold, esp. out of SNA

TCI

Forward blue room (lavatory)

N-1 sync

Pressurization control

Fast slew on the OBI (CDI)

Automatic APU (2)

Fuel counter reset - don't have to hold (3)

Master caution and master warning not too bright (too bright in 50)

Twin heads on com radios (10)

No need to test F/D

Individual volume controls on com radios (5)

Radar easier to use (6)

10-mile range on radar

More positive response on reversing

Digital readout of fuel and gross weight (2)

Radio altimeter design (7)

-80 is standardized across fleet

Reliability high

More engine power (4)

Radar - low power - not afraid to use on ground

Autoslats

ARTS

Dual computers - more freedom to set up different options on the two sides

Location of nav receivers and DFGS - easy for outside scan

Bank angle limiter

Heading bugs can be set on right (2)

DFGS in general (5)

Digital readout to TAS/SAT
High performance wing
Power and ARTS ("lost engine at SNA - problem was slowing it")
Big ADI
Cockpit lighting in general (3)
Turn wheel ("on 50s, captains snap it around")
Glare shield location of DFGS

What do you dislike about the plane or what would you like to see changed?

Suitcase handle (stab trim control) in way of F/O's view of stab setting
Pitches over too fast in leveloff from climb. Have to use pitch wheel to prevent, increasing workload
No groundspeed readout ("light planes have outstripped airliners")
Digital ADF doesn't have the range. I can get NARCO (MSP) 100 miles out in a 50, not an 80.
Night lighting White light reflects in windows.
Need to bring up white lights to see V-speed book (5)
Problem of cancelling capture with vertical speed wheel
CDI knob should be down on or below HSI
Too long to crank in ZFW (2)
M.76 is too low for 37,000. Need chart giving weight-alt-preferred Mach
ADF hard to reach - have to reach over throttles
DFGS is affected by cold prior to startup
VOR tracking logic - turns back to no-wind heading for heading change at station passage (2)
Some knobs look too much alike (Spd/M and heading) (2)
Two DME readouts on same instrument confusing
Slat lights - can't tell if mid or full. Would be better if they said "T/O" and "Land"
Too many turns to set the DH on the radio altimeter (4)
Radar altimeter DH setting only goes to 500 feet
Spd/M and Nav-1 controls too similar to be so close to each other, especially if the nav course and IAS are the same or similar (digital readings in windows).
Chopped off (not full circle) nose gear steering wheel catches mike cord
Landing light switches not aligned - nose light switch slightly higher, giving false impression of being in mid on quick scan
Turn knob should be on pedestal - easier to rest hand (3)
F/O and captain's hands are crossed (on DFGS) - when F/O is PNF and setting heading and capt. is setting altitude
Rheostats on cockpit lighting not linear - on all DC-9s
Digital readouts (2)
The (7-segment) readouts have failed segments, esp. on DME, which gives erroneous readouts
Digital readouts - "I can't scan - have to 'focus' on numbers
Nav frequency selector - can lose decimal portion - usually

solves itself

Autopilot (A/P)

Not hard to learn - basically it's a 50.

On the LOOP-4 departure (SID) from LAX, the A/P blanks out due to rapid climb. Also on MUSEL-4 from SNA, especially on Thermal transition. It can't handle a large bank angle, big intercept angle, and rapid climb. (2) (See Figure 4).

Rough on engage at 800 feet, if accelerating vertically. Should stabilize vert speed before engaging

Love the leveloff, e.g. 2000' at ORD. Never had it go wrong, but have seen captains fail to pull it out (arm alt capture)

Most errors are our own fault

It can bust an altitude on a rapid climb.

Tends to pitch up or down when you engage it. Especially when you are light. Complicated by the $V_2 + 10$ rule. Medium weight $V_2 + 10 = 142$ kts.

No problems. Had one altitude bust. It failed to capture, but I think it was our fault. Long descent from FL 240 to 11,000 and I'm not sure it was armed. Have had one or two "breakoffs" of alt hold.

Good on VOR track (2). Not as good as I'd like - depends on ground station.

I don't turn it on at 800 - I usually hand fly to 10,000.

Out of SNA I was distracted by traffic - speed dropped to V-ref minus 5.

Autothrottle system (ATS)

Excellent (6). Esp. on T/O. Great to set T/O EPR and climb power.

Hard to understand the IAS hold, then the EPR climb or spd select. A simulator will help. The J04 computer has helped. Some guys don't like the low limit - they want the throttles closed.

Hard to learn. Descending at M.76, at 29,000, you pull the power off and go to 310 kts. Can't keep the throttles back at idle. They tend to jump to low lim, but not every time. At cruise I click it off and go to the book.

Best feature on the plane (2). Easy to control spd, esp. in area like LAX where you're going to spd reductions...don't have to work so hard to stay within 10 kts.

Too sensitive in cruise (5). There are large EPR changes, even with the 904. Too frequent changes disturbing to passengers.

Great labor-saving device.

Like it on T/O and climbout (2).

Over level ground it's okay (at cruise), but DEN-PHX the mountain waves cause it to hunt.

Captains are leery of the A/T - its tendency to CLMP. They blame it on the A/T and click it off. Captains try to fly it like it's a 50.

Nice not to have to keep checking airspeed in climb.

Nice in T/O, but it's best in cruise. Hold the Mach.

Has been good since the 904 (DFGS computer).

On descent, it helps to bring throttles up to Lo Lim manually. Gives a bump when engaging after takeoff. Helps to engage while flaps are still at 20 degrees.

On T/O, doesn't clamp properly - too early or too late. On descent, it shut it off a Lo Lim once stabilized, and then turn it back on. But it helps reduce workload.

Too "positive" in corrections. I'd like a sensitivity switch. I'd like it more sensitive on ILS, less at cruise. It's good on ILS. In IMC, I plug it in and fly it down to 100'. Only problem is vert speed adjustment.

Do you like to use the coupled approach on an ILS?

Favorable - no further comment (5)

In IMC, I trust it. Some ground stations poor (e.g. LAS), but I'd still use it in weather.

Excellent - but I get the urge to hand fly.

Excellent if capture angle not too great. Pilot awareness is the answer.

Failed to capture once at MKE. Don't recall if had both Nav receivers on the ILS.

It's perfect. On my first trip, to MKE, the weather was terrible and it was great. Rougher the weather, the better it is.

Dislike - too much control movement. I can fly smoother. We know when to roll in and make drift correction. On a tight approach I prefer to hand fly with the F/D, but I like the A/T for airspeed control.

It does a good job generally. I never fly raw data - I at least use the F/D. In the -50 I sometimes fly raw data.

I like it - I have flown two ILS's with heavy X-wind, and like the way it handled it. Like the programmable bank angle limiter. Normally set it at 15 degrees, but will use 25 for LOC and VOR capture, glideslope capture and track. "I fly this A/C as automated as possible - that's what it's made for." Some concern over automation "clicking off" during an approach.

Trouble free. More you use it, more you enjoy it. First two or three months people clicked it off. Three times I have seen it announce LOC CAP and fly right through it. You have to watch it.

Depends on the station...with a good station, it's excellent. "It's a shame to have to turn it off to make a landing." MSP is good, depending on the lead-in. I use it whenever I can.

We did it on the -30 and the -50, but never used the A/T. I like the logic of the -80 approach coupler. Capture is good, but you can get a big A/T surge at level off. Glideslope capture and tracking good.

Bank angle is important. I make approach with it (limiter) set at 10-15 degrees, and depart with it at 30, especially if you need a big turn, like PHX east departure, or MUSEL-4 from SNA (see Figure 4).

I like to hand fly down from 10,000 in good weather, but would use coupler in bad weather.

"Mixed feelings - if the A/P chokes, you're out of it (the loop). I have faith in the -80 A/P, but misgivings about using it too close to the ground. So far have had no trouble.

Use of automation on visual approaches

It's harder with the A/P than to hand fly.

Harder in -80 than -50 due to the turn knob in the 50.

I like to use automation, including the turn knob. (Interviewee then described in detail a visual approach to 8R at PHX, from

MSP. Enters at about 225 degrees, with heading of 260 preset for downwind (6000 feet). Turns base with heading select (4000 feet) and alt preselect armed, then captures ILS loc and glideslope.)

Easier (to steer with) heading bug until final. With A/T you have more time to look out - don't have to keep checking airspeed.

Don't like it on a high, fast approach, e.g. visual to SAN. I shut off the A/T - it goes to LOW LIM too much I don't use ILS capture on a visual.

I mix automation with hand flying on visuals.

I don't use automation - too much time in the cockpit.

I hand fly using A/T, or use nothing. I am concerned about loss of skills.

I use automation down to 200'

Central aural warning system (CAWS) (see footnote p. 47)

Favorable view - no further comments (4)

It gets your attention

No problem with false alarms

We'll learn more about it in the simulator. We have no opportunity to hear the important warnings (e.g. engine fire).

Easy to interpret - e.g. "FIRE - LEFT ENGINE," but it is not a workload reduction.

It once yelled "FLAPS" on T/O. They were properly set to 11 degrees. It's normally 20, but 11 for SNA. We set 20 on the left side, but it didn't matter.

Don't like "STAB IN MOTION" (this mentioned by most interviewees)

Don't like "ALTITUDE"

Don't like "LANDING GEAR" - can't silence in advance

On a rushed ATC, where they kept you high fast, too much noise. (This pilot silences ILS-related ground prox warnings by switching off the ILS freq)

Generally favorable view, but feel it "talks too much" (4)

"MINIMUMS" message too loud (2)

Should speak only for serious alarms (e.g. fire, stall) (2)

Good, but parameters are too tight on takeoff

Likes the T/O configuration warnings

Likes fire warning and engine loss warnings

Likes minimums warning on R/A

Likes configuration alerts for takeoff.

"In any aural systems, if you have to rely on that, you're already too far behind the A/C to be helped. FAA insists on it (CAWS), but I've never been in a position to need it. At SAN I get sink rate (GPWS) on westerly approach.

"SPEED BRAKE" warning on touchdown unnecessary and is distracting at critical time (3)

It's overkill - esp. clacker plus voice on overspeed

Complaints about "mysterious warnings" (2). On ground, I turned off left generator and got FLAP. Got "ALTITUDE" on ground at MKE. Got false flap warnings on T/O.

Like the 210 knot gear warning logic (4)

Do not like the 210 gear warning logic (4)

Other warning and alerting systems

Would like to have the aural tone (beep) for 1000 feet prior to preset altitude restored (6)

Like it the way it is - light only at 1000 feet (6)

Like ALFA speed protection

On approach to SNA, missed the 4000 for 3000 light - got the voice warning from CAWS at 2600 feet. Had it programmed for 3000 foot capture, but probably hit the vertical speed wheel.

At night, when you start APU during taxi, the master caution light comes on due to low APU oil pressure.

Master caution light too small.

Autobrake system (ABS)

Summary - all comments were favorable to the ABS. Most agreed that the minimum deceleration was adequate for most runways, that medium was needed for short runways, and most mentioned SNA as an airport where ABS was most useful. Most agreed that there was no need for ABS on a long runway.

I use it on every landing, usually at minimum setting. At SNA we use it at medium or maximum, especially at night.

I use it only 5-10% of the time, for short runway or poor weather. I use it at SNA every time. Usually minimum but min or med at SNA.

Especially good on the -80 since it is hard to get the nose down.

Some problem of individual variation in deceleration between aircraft.

Use it 20% of the time. On one landing, the F/O misunderstood me and set it on max. It slammed the nose down.

Dial-a-flap and stab setting computer

Complaints about the flap handle being mechanically difficult to work, hard to seat into gate (detent). (9)

Hard to find 20 degree gate - not a positive gate. Can cause a configuration alert on the CAWS on T/O. (2)

Talk to the man in the right seat - he does all the work. We usually go with standard settings (and don't use dial-a-flap).

Dial-a-flap adds to the workload, but it's at the gate. It is not being used to full efficiency - we need (takeoff) charts.

I like the flexibility it gives. (2) Special mention of summertime T/O from DEN and PHX.

Not sold on it. It's a pain to spin it so long just to get 20 degrees; same for stowing. Stab setting window hard to read. You don't even need the number in the windows, just align the pointers. This is a busy time - setting the CG, MAC, stab etc.

Not worth the trouble - just add a 11 and 20 degree detent. No need for stab window. Just line up the pointers. If you go by the window and not the pointers, you'll get a configuration warning.

Probably no need for it (dial-a-flap) since you have so much engine power.

Why not a 20 degree detent? It's the only T/O setting we use.

Complaints about "opposite rotation" of dials (numbering system in opposite directions). (5)

Works fine. Not a workload problem. F/O has to lean way over to set the CG.

Wasn't taught a procedure, so I developed my own -- six steps. That's too many steps just to set the trim.

Stab and CG pointers do not line up on the same number. (2)

You need a light to see the green index at night. I use a flashlight.

It's extra workload. I prefer to go at 11 degrees (flap) so I don't have to fool with it.

Pressurization control

Note: at the time of the first wave interviews there was some disagreement about the proper way to operate the pressurization system on the 80. Most of the comments dealt with that question. To explain briefly, the recommended procedure called for setting the destination altitude at the gate. An alternative procedure arose - setting in the cruise altitude by determining (from the linear scale) the field altitude setting that would correspond to the cruise altitude, then setting the destination altitude as before, on the way down. Interviewees, particularly F/Os, held rather strong opinions about the proper procedure.

Standard procedure (never setting cruise altitude) (6)

"Set it on the ground and forget it" (2)

"It's beautifully designed"

One captain reported he didn't know there was an alternative procedure

"Set it at the gate - less workload"

"I've tried both ways - now I just leave it alone"

Alternative procedure (7)

"I set cruise altitude, then set destination. It doesn't reduce workload."

Other comments -

Window reads in 100' -- 1000' in all other DC-9s

"I set it the way the captain wants it set"

"Easy to make a 'times 10' error - setting 700 for 7000"

Excellent. Very accurate

I set 33,000 instead of cruise FL, esp. if we are going high. I set TDZE instead of FE for landing. At LAS, there's a 100' difference on R/W 26 and you get a bump (on depressurization).

Potential loss of proficiency due to automation

No problem since we fly the other DC-9s too. (2) I hand fly complex procedures like MUSEL-4 SID (SNA) (See Figure 4). Easier for me than to keep checking DFGS. This is what a check pilot did on my checkout.

Sometimes I fly the F/D only, though I prefer to fly full automation. I never fly raw data except on back course. No concern for proficiency loss - I just had checkride - thought about it a lot, but had no problem.

Some concern. I can already see a loss in skill, but will make up for it with more hand flying. In IMC I always use A/P and F/D. In VMC, I'll use F/D only, or even raw data.

Problem is not just automation in 80, but fewer legs. We are used to 10 legs a day, now in -80 it's four. I should do more hand flying.

Just had a checkride in a -10 simulator -- no problems. Company wants you to use automation 99% of the time -- no problem for experienced DC-9 pilot, but for new pilot it could be.

I have some concern. In VFR I hand fly. In IFR, I fly F/D only some times. If I'm hand flying and I get ATC call, I'll throw on the A/P. There would be no problem if I had to take a -30 checkride.

I'm worried, so I hand fly one leg each trip. It hand flies so nice it's fun to do. I would have no worries about jumping in a -30.

Workload and fatigue compared to earlier DC-9s

Workload

"slightly less" (8)

"slightly less, but not the 40% less they (manufacturer) claim"

"20% less" (3)

"25-30% less"

"50% less"

"Considerably less"

"No difference" (3)

More (2)

More mental workload, but overall less

Overall less due to the longer legs in the 80, not the equipment.

Overall about the same, but can do more at the gate, and less to do at peak times in flight (2)

Less time to look out to window

If you've armed it, you have to monitor it like crazy. So there's no real change in workload. You still have to keep bringing your head back in the cockpit to be sure it's working.

There's more workload at the gate. It's easier in a -30. It's a fallacy to think that the gate isn't a busy time. There's hazardous cargo, call for alternate, armed persons (law enforcement personnel), fuel not right. There should be more emphasis on command responsibility at the gate.

I'm "old school." I spend a lot of time seeing that it (automation) is doing what it's supposed to do.

Less workload as long as things are ideal

More workload if you're above the glideslope. ATC doesn't know you're an 80, so they turn you too close. Should have a different designation of an -80 with ATC. *

* Note: this fact was mentioned by several pilots, and it was true at the time. ATC has since changed its procedure and carries an MD-80 designation on its flight strips.

Fatigue

"no difference" (2)

"slightly less" (3)

"far less"

"I'm not used to sitting for three hours"

Less, but probably due to fewer landings

If you could have one more piece of equipment in the -80, what would you want?

Groundspeed readout (4)

HUD

Aural altitude warning (like -50)

PDCS (performance data computer system) (4)

Rearview mirror to see wingtip lights

Direct ARINC link to update weather

Illumination of V-speed card

Pencil holder

ACARS

Nothing (2)

Strobe lights

Would rather standardize our whole DC-9 fleet

Angle of attack indicator

Remove DFGS and put in -50 avionics

Long range navigation system (5)*

* Includes RNAV, Omega or INS. One pilot commented, "it would have to be cheap - I'm using Center's computer right now at no cost. I can get MSP direct Hector (VOR east of Los Angeles) about half the time."

WAVE TWO INTERVIEWS

Why did you bid the DC-9-80?

Brand new plane. I like automatic systems.

Pride

Schedule -- I was a bottom block holder.

The long legs

General comments about the -80 and automation

Contemporary plane - I missed it when I went back to the -30.

DFGS can be overwhelming - I just snap it off when things get complicated.

Too much pitch change in descent, esp. in wind changes. Due to this I'd go to vertical speed and control with wheel.

Many electrical glitches that self correct.

If you don't fly the -80 regularly, you get behind the eight ball.

The good points of the 727 are in the -80 (A/T, ABS, alt. alert, pressurization controls). S/O in Boeing has nothing to do -- I fought with the F/O just to see who could get the ATIS. In the -80, you're in the loop all the time.

It's not worth the money (5). Could get by with the -50 configuration.

Have flown all of Republic's planes. No comparison. The -80 is the top plane.

Totally impressed by the plane. No problems, even out of SNA.

-80 is a new generation plane. It requires a new philosophy of flying. Differences (with older DC-9s) are underestimated -- it's a whole new world. You have to stay in touch with the plane. The secret is the FMA. Now that we have a simulator, we should start all over. (Recommends more simulator instruction with LOFT). There is a dangerous sense of detachment, e.g. auto G/A. I saw no value in the static airplane training. Would like a CSS, or at least a "board" you can get your hands on.

At my age DFGS is a problem. Wish the company hadn't bought it.

First six months it was like flying a pinball machine. Computers

couldn't take (power) interruption. Use external power at ramp and things would go black. If you lost external power and started on APU or battery, you'd lose the computers. Got a F/D flag on captain's side all the way to PHX, landed and the F/D came back on. *

Job is becoming too much button pushing. Company shouldn't tell us when to use it -- should be our choice. I want my job to be more interesting.

On climbout, everything (DFGS) went blank. Switched to other computer (DFGC) and got nothing. Later it came on.

Older captains have trouble learning DFGS, speed control, difference between spd/M and A/P pitch to control speed.

Took me 150-200 hours to feel comfortable. If anything comes up, I want it (automation) off.

We spend too much time (looking) in the cockpit. I want one man looking out, esp. at SNA. Can't be fooling with DFGS in a high density area.

-80 is a well designed machine. If mistakes are made, it should be in the first 100 hours. Two new people flying together spend too much time programming. The simulator will be a big help.

I've ridden in back. Good, quiet ride. Passenger comments are good. Had a highly experienced passenger tell me that business coach in our -80 is the best ride available.

ATC is changing its mind more and more. It's a bigger problem in the -80 than the -50...all your programming goes out the window. So I click it off. If I'm out far enough, I try to reprogram.

With automation, you have to stay ahead, esp. G/A and missed approach.

I love the -80 -- it had gremlins running around in it. At MKE on a cold morning, no FMA, no A/P. Come on when we warmed up. Had trouble in cold weather. The -80 compared to a generic is like a Cadillac compared to a Model T.

Occasional crossed hands. Captain as PNF (pilot not flying) setting altitude, while F/O is PF (pilot flying) sets the speed bug.

Big variation in captains' ability to handle automation.

* Corrected in later models of the DFGC.

Confusion between heading and altitude when the numbers were the same (due to digital display).

In automation you're out of the loop. In hand flying, you know what is happening.

Programming is simple, once you understand it, but paying attention to what you have programmed is time-consuming.

What do you like about the plane?

More stable

Quiet cockpit (3)

"Gadgetry"

Radios (esp. twin heads) (11); individual vol. controls

Ability to program ahead

Digital fuel display (3); "gives you all the information -- much better than the needles"

Backup ADI and altimeter

Radio altimeter design (5); "minimums" voice message

EPR bugs and preprogramming; esp. for power reduction at SNA

Both DMEs on same instrument - "I don't like to look around cockpit"

Autobrake (7); esp. BUR R/W 07 after rain storm; esp. at SNA

Automation in general (4); esp. in terminal area or step climb

Power and performance (7); esp. 8R out of PHX with full load; can take off DEN at 100 degrees F with full load; can use north R/W at PHX.

Quick zeroing of digital fuel display

Self test of slats

No uplatch check (gear)

Digital readouts in general, except when they go black

Test of radar altimeter

Standby airspeed indicator

Color radar

Pressurization

Large F/D

TCI

Test lights

TAS readout

General layout of cockpit

Autothrottle (3); "down to the knot"

Coupled approach

Fuel economy

Ability of F/O to couple A/P

Versatility of DFGS -- ability to use some or all (2)

Digital ADF

Back angle select

Vertical speed very accurate

Strobes

What do you dislike about the plane, or what would you like to see changed?

Digital displays (5); "with needles you can catch something out of whack"
Radar altimeter takes too long to set (3)
Cockpit lighting, esp. on V-speed book (6)
Aural feedthrough on ADF ident and VOR ident
None (so stated)
Too sensitive to engine ice
"Entire logic of DFGS doesn't take wind into account, then over-corrects. Likewise on glideslope with gear and flap changes"
Radio altimeter limited to 500 feet; some non-precision approaches have MDA over 500 (2)
Trouble setting ZFW
Flap-stab-CG computer too complicated
Pressurization -- should use Boeing system to set altitude
Weight and fuel readout - should have separate counters for gross weight and fuel weight
Crew bags shouldn't rest against circuit breaker panel. Need a place for bags. A bag can hide a popped circuit breaker.
No place to put pencils. In the generic DC-9s, should stick it between the glare shield and the side. No place in -80.
Leave the DFGS readouts on the panel, but put the control back on the pedestal

Autopilot (A/P)

Only time it failed to capture was when we did something wrong

Several mentions of problem of touching pitch wheel killing altitude capture

F/D too sensitive compared to -50. Have to work harder to fly F/D approaches

Too many problems -- failures that can usually be reset by pulling circuit breakers. Ground school didn't teach us to cope

DFGS is marvelous once you learn to use it. Could fly MSP-LAX and never touch the airplane (primary controls). Never had trouble except that which I caused. Can't fly ATC now without an A/P -- I'm an "autopilot freak"

It tends to pitch up when you engage at 800 feet. If you reduce vertical speed fast enough, no problem. No problem after engagement.

Difficult to set 100 foot level in altitude select, e.g. initial approach of 4700' on BUR SID, 3100' on FHX visual. Could

actually change 1000' while trying to set 100'

Altitude arm doesn't always stay in detent...can fall to adjacent altitude

In moderate turbulence, A/P shakes off. Takes very little turbulence to disconnect it

Autothrottle system (ATS)

Generally favorable comments (4); surprised how accurate it is at cruise; use it all the time -- big improvement

Had to learn how to set it on descent

A/T surge is a problem. IAS hold is not always smooth

Great for flying around thunderstorm and holding airspeed. Big relief of workload

Didn't realize how good the A/T was till I went back to the -30...it's excellent on the -80

We don't monitor it enough. I'm concerned that it will clamp short of takeoff power

Do you like the coupled approach on the ILS?

It "fight's itself" too much on capture. I've had it fly through LOC and not capture

Ok in good weather. I hand fly so I don't get spoiled. Fails to capture LOC maybe 1 in 20 or 30 tries. Only once on glideslope. I like the preselect -- it makes a smooth pitch maneuver even at 3000 fpm.

Very favorable. Sometimes a new captain would right up the A/P when the problem was too severe a capture angle (on LOC). Good glideslope tracking, even if you capture too high

Generally favorable...use it 25% of the time. On short approach you don't have time. Big adjustment in -80 is to get it down in time

Use it all the time. Gives me more time to look out the window. Airport congestion is the big problem with a two-man crew

Captures and tracks very smoothly...better than I can do it. I use it always, unless I know the ILS is unstable, like at LAS.

Use of automation on visual approaches

Prefer to hand fly with raw data

At first didn't use automation, but now use it all the time.
Beautiful for approach to PHX

In IMC, ATC sets you up for using it; in visual, you don't have time

Central aural warning system (CAWS) *

Generally favorable (4)

A few warnings are unnecessary, and confusing at first

Too loud and overwhelmed with warnings (2)

Fire test can be heard by passengers

Objections to "SPEED BRAKE" on touchdown (4)

"SINK RATE" too loud

"MINIMUMS" too loud (2)

Likes configuration warnings (3); "tells you exactly what's wrong"
Good safeguard, but too sensitive

Too much talking if there's an emergency, e.g. "ALTITUDE" warning on ILS when captain's talking. But it's better than beeps and tones. The lady pinpoints the mode and tells you what the problem is. You don't have to remember the modes that trigger it, e.g. parking brake set at takeoff

Likes "OVERSPEED" warning

Dislikes use of woman's voice on CAWS messages

Too much voice warning (3); if it's a real problem, could be a hindrance, e.g. "minimums" on radar altimeter is a distraction. PNF and plane are both yelling "minimums"

Should only annunciate abnormal conditions

Likes 210 speed for gear warning

Dislikes 210 kts...should be lower

* See first footnote page 47.

Other warning and alerting systems

Misses having aural tone on altitude alert (8); you need it more in -80 than other planes since you rely on automation more; possible altitude bust at a busy time -- taking ATIS, briefing on approach plates; should be consistent with other DC-9s

Likes the altitude light (in place of tone)

Too many aural and visual warnings

Blue lights (A/P-1, A/P-2, F/D etc) too inconspicuous

I get warnings due to staying ahead...trying to be more efficient by staying high longer

Difficult to set altitude alert by 100'. As you release it, it changes, esp. when done from captain's seat

Autobrake system

Favorable view (6); esp. SNA; top feature -- I use it every time

Note: all comments on autobrake very highly favorable

Dial-a-flap and stab setting computer

Loading is critical. If incorrectly loaded, fuel burn goes up. Had a 2800 pound overburn MSP-PHX

CG computer is Mickey Mouse. Pointers don't line up. It's more work

Hard to seat flap handle at 20 degree dial-a-flap

They would have done as well to put in a 20 degree fixed detent

Pressurization control -- no comments Wave Two

Potential loss of proficiency due to automation

No problems when I went back and took a proficiency check (PC) in a -10 or -30 simulator (9)

PC in the -30 simulator a little rusty

Best PC (-30 simulator) I've ever flown

Recognized potential problem, but could be offset by hand flying (2); we get enough experience with non-precision approaches (to keep proficiency); I always use automation in bad weather, or at the end of a long day...otherwise like to do some hand flying

Can lose proficiency if you overuse automation. Happens in the summer, then come October we feel it. I realized I had become "soft" when A/P failed and I had to hand fly PHX-ORD

No problem, esp. if you hand fly something like an ADF approach

No problems going back and forth from -80 to generic

Definite scan pattern loss flying the -80, but regained it in one trip in a generic

Note: the following comments apply to "backward transition" as occurred to LAS crews following reassignment to older DC-9s after a considerable time on the -80. There is not a corresponding section in the Wave One interviews, since the separate status did not exist at that time, and most -80 pilots regularly flew the older DC-9s as well. All pilots that had done backward transition agreed that it was no problem. What little loss of proficiency ("loss of scan") that may have occurred was quickly regained when flying the line on the older DC-9s.

I was spoiled. But the -30 is more fun to fly, a more relaxed atmosphere. I don't think I would ever like the -80 more than the -30, though the workload had become less. The emphasis in -80 automation is in the wrong place -- guidance, flying to altitude, tracking station is not the problem

I missed the "fancy stuff". I was on the -80 long enough to learn to trust it (500 hours). I would have liked reorientation training in the generic. I went right out on a -10 and flew a 200 and 1/2 approach to minimums. The separate status in the -80 is a good thing. I love electronic toys, and miss the -80

Took a PC instead of a training ride. No trouble. Nice to have the beep (aural altitude alert) again. I missed it on the -80. I relied on automation too much in the -80.

Workload and fatigue compared to earlier DC-9s

Less workload - it does so much for you

Slightly less workload (3); at first more...simulator would have helped shorten this period.

Less workload, but not as much (less) as Douglas says

No reduction in workload

Took 150 hours to get comfortable, but once you're used to -80, there is more time to look out

A little less on long legs, but more on short legs

All told, more workload, but automation smooths the peaks and valleys

More time with head in the cockpit

No reduction of workload, due to increased monitoring demand

Preprogramming allows you to avoid high workload, e.g. BUR. But workload can be higher, e.g. ATIS tells you the runway, then you get a sidestep

Workload is higher for the F/O on the ground -- CG, stab etc. Not for captain. This is a critical time: checking fuel, preparing for pushback. (Suggests putting fuel check earlier on checklist)

Less fatigue in -80 (3); but may be due to easier trips (1)

Policies, procedures, and training

Note: no comparable section in Wave One.

Favorable view of separate status (5); should have been that way from the beginning; never should have treated it as just another DC-9; company tried to "low-key" differences -- we need continual training on differences

Comments on inadequacy of differences training (4); CSS needed; "difference class a waste of time -- color slides don't do it"; Training is "much too light". I had trouble grasping DFGS. Needed some hands-on experience. Even a CPT would help. Too much talking about it. Even sitting in the plane would help.

Would like a 60 day proficiency rule in -80 (in place of 90 days)

Objects to company insistence that automation be used all the time

15 degree flap on taxi -- not enough time to lower flaps for takeoff. Have to "lead" it, esp. at SNA -- R/Ws only 100' apart, and you get rushed. (2)

I don't think the company uses the A/P to full advantage; e.g., taking off in heading select -- could take off in heading hold.

Would have been easier with simulator. Our pilots, especially Vietnam era pilots, are excellent

First 2-4 trips were awkward. The CSS at Douglas didn't work. A -80 simulator would make a lot of difference, especially with visual capability.

It takes 2-3 trips to get comfortable, but I lost this when I didn't fly the -80. I forgot little things.

If you could have one more piece of equipment in the -80, what would you want?

Ground speed readout (3)

Separate heading bugs (controls) (2)

Mirror to see the wingtip

Long range navigation (2) *

Collision avoidance system (CAS)

Nothing - don't see the need for a PDCS...we didn't use it in the Boeing. No need for Omega, given the fact that ATC will with you on a vector but won't give you Omega direct

* Includes Omega, RNAV, and INS

VII. DISCUSSION

The Opportunities and Hazards of Field Studies

No field study is ever fully representative of the industry. The airlines are all different, and the pilots who have transitioned into the -80 at other airlines differ in many ways from those at Republic. For example, most of the DC-9-80 operators have transitioned crews from aircraft other than DC-9s: from 727s at PSA, 737s at Air Cal, and from a variety of aircraft at two trunk carriers that have obtained the -80, TWA and American. Thus, other carriers have transitioned flight crews from Boeing to McDonnell-Douglas products, and in most cases (Air Cal being one exception) from three-person to two-person cockpits. At the two trunk carriers mentioned, some of the pilots may have had prior experience with sophisticated flight-deck automation, for example, junior captains who had flown as first officers in 747s, or in DC-10s (AA) or L-1011s (TWA).

Republic probably represents the "purest" case -- all of its DC-9-80 crews came directly from older models of the DC-9 (-10, -30, and -50 models). Most were highly experienced DC-9 pilots, and with the possible exception of military flying, were encountering modern automatic systems for the first time.

Furthermore, an airline operation is not a pristine laboratory, far from it, especially in the period following the Airline Deregulation Act of 1978, and the economic hardships that followed. In the harsh environment of deregulation, high fuel prices, and high interest rates, this study became "event driven." As soon as the project began, economic factors made it necessary for Republic to delay its acquisition of the Super 80s, taking only three in 1981 and three more in December of 1982. This impacted the study by making it somewhat difficult to build a panel of participants. Many of the roughly 100 Minneapolis pilots who initially went through the differences school had no opportunity to fly the -80 after their training, and many who did flew mixed blocks with a majority of their time being in older models. Several of the pilots who originally volunteered for the panel never flew the -80, and hence did not fill out questionnaires or participate in the interviews. The Las Vegas panel was more stable, due to the imposition of the "separate status" rule in September 1983 (see Page 85, and Page 96, Paragraph 10). Most of those who bid and were trained for -80 operations tended to stay with the airplane, until just prior to the closing of the Las Vegas domicile in August 1984.

At the same time, the overabundance of -80 qualified pilots in Minneapolis provided an opportunity to look into the matter of crews flying both the older models and the automated -80 during the same month, even on some pairings the same day. Also, many of the pilots who qualified in the -80 bid other blocks, and then

bid only occasional trips in the -80, and many fell out of qualification (three months) and had to be requalified, to the concern of management. Again, this offered an opportunity to gain some insight into the question of skill maintenance in a new aircraft. So the economic hardships that delayed the delivery of the aircraft provided both difficulties and opportunities for the study. Also, for the reasons stated above, this study did not turn out to be purely longitudinal, but more a mixture of longitudinal and cross-sectional techniques, since there was some change of panel members from the first to the second wave, particularly in Minneapolis.

Pilot Opinion

Line pilots often express the sentiment that their opinions and experience are under-represented in the design and certification of the craft they fly. Most feel that aircraft manufacturers, in their design work, and the FAA in their certification, do not make sufficient use of the experience of line pilots. They further protest that when airline pilot input is sought, it comes from management pilots, ranking officials of the flightdeck unions, and others whom they perceive (rightly or wrongly) as remote from the every day rigors of line flying. Whether this view is correct or not, or possibly correct but exaggerated, is not the issue. The sentiment is mentioned here for two reasons.

First, it is not only appropriate, but necessary to remark on the motivation of volunteers in any study. It became very clear in the interviews that the pilots volunteered largely because they felt that participation in the study would allow them, in some small way, to influence future air transport design and certification. This feeling was engendered by the invitation which was distributed to the pilots asking them to join the study, and by the chairman of the union Safety Committee. In his appeal to the pilots in support of the study, he stated (to paraphrase as closely as possible), "You complain that nobody cares about your opinions on cockpit design -- now here is your chance to be heard."

The second reason that pilot opinion is mentioned is that aside from their complaints that they are under-represented in design and certification decisions, crews represent a vast and valuable "database" of experience that could be tapped for evaluating cockpit design. In a short time after a new aircraft is introduced, considerable data are generated, information that could simply not have been anticipated in the design, testing, and certification process. In a very real way, line flying "shakes down" an airliner and pilot opinion harshly examines the soundness of the cockpit design. Thus, it is hoped that the data reported here might influence operational and training decisions, certification techniques, future flightdeck designs, and

development of principles of automation. Likewise, this study may be valuable by dismissing some areas thought to be of concern, where the concern is seen to be unjustified.

However, we must recognize pilot opinions are extremely variable. This may indeed affect the degree to which studies of this sort may influence future design and training decisions.

Overall View of Automation

For purposes of this discussion, we shall include not only those equipment items which are unquestionably "automation", that is those in which previously manual functions were replaced with devices or eliminated (e.g. autobrake), but also those new features of the aircraft which were designed to reduce workload or add to the versatility. For example, the dual head communication receivers are in no way automation, but they do reduce manual operations by making it unnecessary for the PNF to write down the new frequencies prior to a frequency change. Also, changes in instrument design, such as the vertical scale radio altimeter, and the digital displays, will be discussed in this report for the same reason. In the mind's eye of the pilots interviewed, all of these features are intertwined with automation, and they do not bother with distinctions between automation and other features of the aircraft.

Overall, a favorable though mildly skeptical bias toward automation emerges from these data. The mean responses on the positive items on automation were quite positive (high agreement) and likewise there was generally strong disagreement with the negatively worded items. For example, the responses to three essentially negative items (No. 2, 6 and 19) were mildly rejected, and those responding to the positive items (No. 8, 9 and 10) showed a mean indicating acceptance. It is interesting that those items that linked automation to economic well-being of the industry (No. 18 and 20) yielded more negative responses, with means near mid-range or slightly below. No. 29 which dealt with the safety implication of excessive automation ("Too much automation can be dangerous") received near-center means, with wide variability.

Since much of the interview data and responses to open-ended written probes dealt with specific features, as well as pilot workload, these will be discussed under the workload section. These results can be summarized broadly by saying that the general reaction to the cockpit design was favorable, and was most favorable to the "automation" related changes. But there was also considerable criticism of specific items that were perceived as poorly designed, or increasing workload. Also,

as mentioned previously, there was no overall endorsement of the economic or even the safety impact of automation. As for the

economic argument, it must be recalled that the first wave of questionnaires and interviews occurred late in 1982, when the economic fortunes of Republic and most other airlines were at an all-time low. Wave Two occurred in 1983 in Minneapolis, and 1984 in Las Vegas, at a time when the economic situation of the airline industry was brightening, due to a general upswing in the economy, a slight drop in fuel prices, and wage and productivity concessions by the airline unions.

On specific equipment and capabilities, the responses were again generally favorable toward automation and specific devices, and toward the Super 80 in particular. There seemed to be high enthusiasm for the Super 80, as seen in the strong agreements with the positive statements (No. 31, 33, 35, and 36) and rejection of the negative statement No. 32. Note that Item No. 31 ("I think that the -80 is a significant step forward in short and medium haul aircraft") received the strongest (positive or negative) mean rating of all of the 36 items. Again, those items that dealt with the operational limits, and hence economic factors and impact on the company, received a mixed to generally cool reception (No. 22 and 24).

Further general endorsement of the automation features of the -80 can be seen from the frequency-of-use data (Table 4-A and B). The mean frequencies indicate an overall acceptance of the devices, as well as the company policy that equipment is to be used where appropriate. For example, the ATS was shown a mean usage of 98-99% on takeoff, and in transition and enroute climb, but was used with a mean of only 73-86% of the time in cruise. This would indicate a wide acceptance of the value of the ATS at the workload-critical portions of a leg, but some unwillingness to accept its instabilities at cruise, where the workload is minimal.

Finally, it is interesting to note the moderately favorable attitude toward and lack of concern for equipment reliability (No. 25, 26 and 28), especially in view of the fact that the early model flight guidance and autothrottle computers had some rather negative characteristics which were corrected in later models, and several of the interviewees expressed concern over equipment reliability and the possibility of sudden inflight failures. Several related incidents of what they described as "data dumps" (total shutdowns) of the flight guidance computers after takeoff.

If one could summarize the pilots' attitudes in one sweeping statement, it would be something like this: "I like the airplane, I enjoy flying it, I approve of certain features and not others, I find a moderate reduction in workload, but I seriously question whether the automation positively contributes to safety, and I question whether it is a good investment at the price."

Perceived Workload and Fatigue

Terms such as "workload" and "fatigue" are widely used in man-machine systems, and are poorly defined, difficult to measure, and impossible to predict. For purposes of this report, these terms will include whatever the pilots intend them to mean. If the pilot refers to the number of times he must twist a knob to set the ZFW as "workload," then it is included here. Mental workload could include those cases where no overt or observable activity takes place, for example planning where to begin descent in order to make a crossing restriction, or mentally computing actual versus planned fuel burn.

Since workload reduction was at the heart of the design and certification of the -80, as mentioned in the introduction of this report, it will be discussed in some detail. Much of what is reported by the pilots in the open-ended probes and the face-to-face interviews dealt with their perceptions of the workload question, including broad generalities (as also probed in several Likert items), as well as discussion of specific systems and equipment items. This section necessarily overlaps with one which follows on specific features in the cockpit.

First, the attitude scales (see Table 3-F) make it clear that the pilots express a positive attitude toward the role of automation in workload reduction. The strong positive endorsement of Items 14, 21, and 27 vouch for this, as well as the weak rejection of the negatively worded Item 15, 17, and 23. Overall, Item 27 ("Automation reduces overall workload") tells the story - a mean of 66 and 70, corresponding to mid-level agreement. In the Wave Two results, the standard deviation was lower than usual on this question, indicating less divergence of opinion. While responses to this item reflect a generally favorable view of automation as a workload reducer, when asked in interviews to quantify the degree of reduction, the replies reflected a perception of modest reductions.

Comments from the check captains also express a favorable view of workload reduction in the -80, though they, like others, draw a distinction between the experienced and inexperienced pilots. Throughout the interviews, pilots expressed the belief that the first 50 to 100 (some said 150-200) hours on the line in the -80 were very difficult, and a considerable amount of time was spent trying to understand the automatic systems, monitoring and interpreting the FMA messages, and programming the A/P and A/T, especially in terminal areas. Many said they had their "heads in the cockpit" far too much during that period, but after they passed the critical experience level, and became at ease with the automation, they noticed a reduction in workload, and more time "out the window." More will be said of the initial transition period when training is discussed.

Asked to estimate the workload reduction on the -80 relative to older DC-9s, about 2/3 of the crew members replied "slightly less", and the rest were divided between considerably less to no difference. A few reported that they felt that the workload was increased, due to what they perceived as an increase in the monitoring ("scanning") demands. And it was generally recognized that to some extent, the total workload may have been less reduced than redistributed, with more subtasks to perform at the gate and fewer in the air, which they recognize as a plus for air safety. Several mentioned that "actual" workload had been reduced, but there was an increase in demand for monitoring, a point especially emphasized by the check airmen.

These last points are consistent with the views advanced by Wiener and Curry (1980). A good example is the altitude and heading preselect functions of the DFCS, which allow the crew to set up for a SID while still at the gate. These, coupled with the ability of the A/T to control airspeed during climb, clearly reduce the workload during a critical phase of flight, and one in which extra-cockpit scanning during VMC conditions is essential. The favorite example seems to be the MUSEL-4 SID from SNA, with Thermal transition (Figure 4). This is a complex departure, coupled with a required noise abatement power reduction at 1000 feet, in an area with high VFR traffic and marginal VMC weather ("California VFR"). There can be little doubt that the avionics and automation of the -80 make execution of this departure easier and safer; how much so is impossible to measure.

Other features that, in the pilots' eye, reduce workload include the pressurization control, and the A/T system in general, despite earlier complaints about its instability.

Actually there are probably two classes of workload reduction. The first would be those already mentioned, such as the altitude and heading preselect, and IAS/Mach hold, devices that can be programmed and will then essentially relieve the pilot of continuous control, anticipation, and capture maneuvers. The other category might be called procedure elimination, devices in which certain procedural steps required in the earlier models are not required, e.g. the automatic pressurization control, which eliminates one step, and the dual head communication receivers, which eliminate writing down frequencies. A frequently mentioned eliminated step is the landing gear uplatch check. While this was not eliminated by automation, the pilots do not make this distinction. They view any elimination of steps as workload reducing and view it favorably, especially when, as in the case of the uplatch check, the relief comes at a time of perceived heavy workload or criticality.

Figure 4

JEPPESEN

JUN 5-81

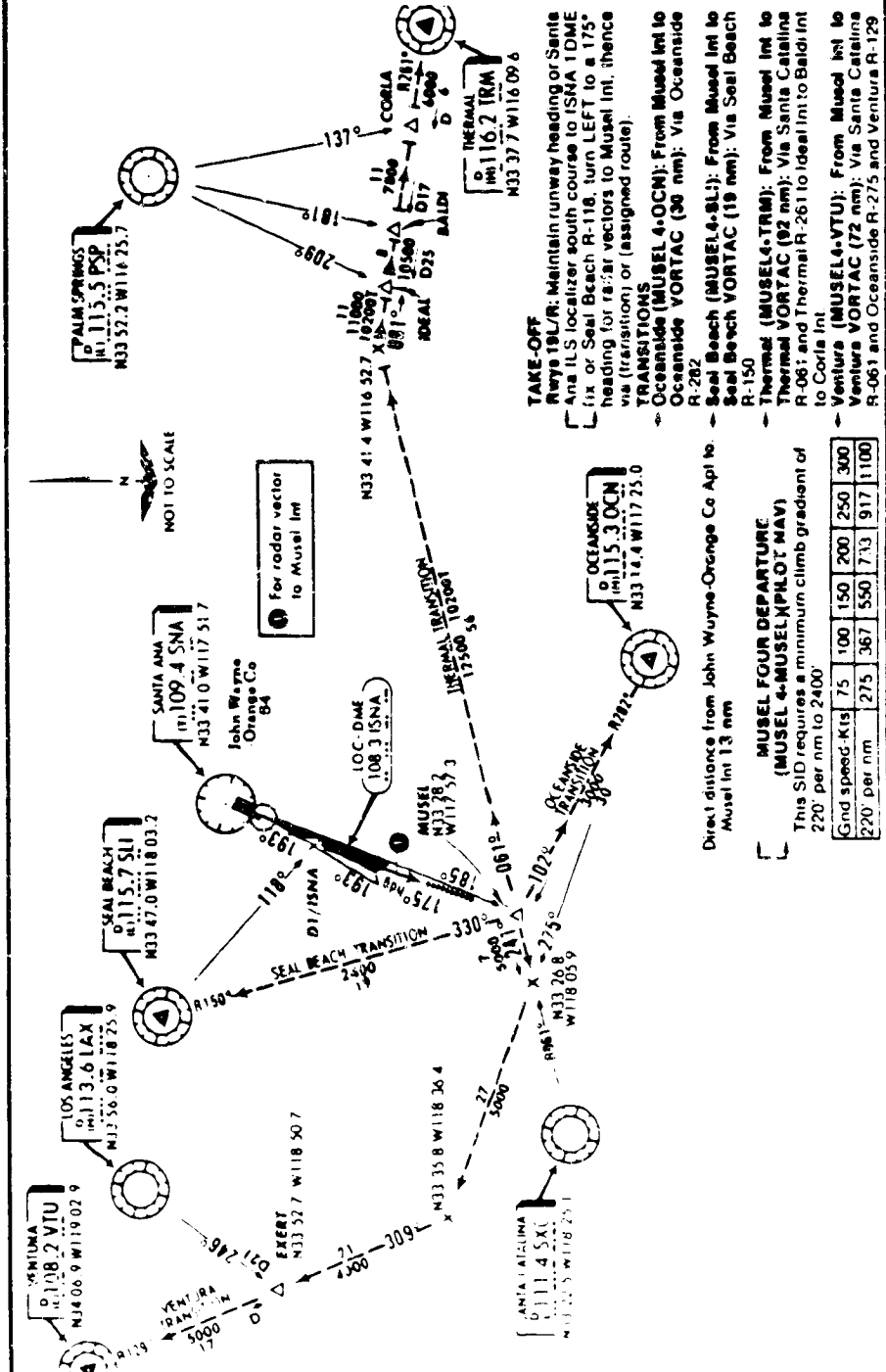
10-3

11

SANTA ANA, CALIF.
JOHN WAYNE-ORANGE CO

510

MUSEL FOUR DEPARTURE (MUSEL 4-MUSEL)(PILOT NAV)



TAKE-OFF
 Runway 18L/R: Maintain runway heading or Santa Ana ILS localizer south course to ISNA 1DME fix or Seal Beach R-118, turn LEFT to a 175° heading for radar vectors to MUSEL Int; thence via (transition) or (assigned route).

TRANSITIONS
 Oceanside (MUSEL 4-OCN): From MUSEL Int to Oceanside VORTAC (30 nm); Via Oceanside R-282
 Seal Beach (MUSEL 4-SL): From MUSEL Int to Seal Beach VORTAC (18 nm); Via Seal Beach R-150
 Thermal (MUSEL 4-TRM): From MUSEL Int to Thermal VORTAC (92 nm); Via Santa Catalina R-06; and Thermal R-261 to Ideal Int to Baldi Int to Coria Int
 Ventura (MUSEL 4-VTU): From MUSEL Int to Ventura VORTAC (72 nm); Via Santa Catalina R-061 and Oceanside R-275 and Ventura R-129

Direct distance from John Wayne-Orange Co Apt to MUSEL Int 13 nm

MUSEL FOUR DEPARTURE (MUSEL 4-MUSEL)(PILOT NAV)

This SID requires a minimum climb gradient of 220' per nm to 2400'

Grnd speed: Kts	75	100	150	200	250	300
220' per nm	275	367	550	713	917	1100

CHANGE: Dep. (as completed, Ventura transition)

There seems to be little agreement on the subject of monitoring as a workload item. This is one of the areas where the check captains appeared to differ (in interviews) with the line crews. The check captains placed heavy emphasis on monitoring, especially in keeping a constant check on the FMA each time an option is selected or a maneuver (such as altitude capture) is entered. The line pilots appeared to be somewhat less concerned with monitoring activities, and it is interesting to note that the Likert item No. 17 ("Automation does not reduce workload, since there is more to keep watch over") received a weak mean rejection.

As mentioned previously, most of the crews felt that the -80 brought only a slight workload reduction. This may be in part due to the fact that there were certain features of the -80 which, in their view, increased workload. In the interviews, opinions about these pieces of equipment and features took on great importance. Specific features of cockpit equipment will be discussed shortly, but for now some of the features that are seen as increasing workload should be mentioned. As in the case of the perceived workload reducers, some of these are automation related, some are not. Most frequently mentioned items are the slat/flap handle which is difficult to seat, especially when using dial-a-flap options; the necessity to stow the dial-a-flap after takeoff, which requires considerable manipulation of the dial; and the setup of the stab setting computer (at the gate), which is seen as containing unnecessary and even erroneous information, since the two readings of CG do not exactly agree, even when the pointers are precisely aligned. The contra-rotating numerical scales (one way for the longitudinal trim window, the other way for the CG and flap windows) were frequently mentioned as troublesome.

Certain features are difficult to describe in their workload impact, since they require management, but eliminate certain steps, and the net effect is not clear. The best example is the autobrake, which is well accepted by the crews, but does add checklist items even when not used. In spite of this, the ABS is perhaps the single new feature about which the author heard no complaints, and Table 4 indicates that it is used on a mean of 56-63% of the landings. Company policy prohibited its use on takeoffs (for braking in case of rejected takeoff).

In summary, the perceived workload management of the Super 80 is viewed as a modest improvement over the older DC-9s, but probably far less than claimed by the manufacturer.

Finally, the matter of fatigue was discussed with the crews, but yielded little additional information, since they tended to see fatigue and workload reduction as the same thing. Likert items No. 27 (overall workload reduction) and 30 (overall fatigue) got similar mean ratings (66-70), indicating very positive acceptance of positively worded probes, and the

intercorrelations between the ratings in both waves were statistically significant. The only new information garnered regarding fatigue was a secondary effect of the acquisition of the -80, the fact that longer legs were being flown, the extreme being MSP-LAX which is about three hours. Several pilots commented that they were not accustomed to long flight segments and found "sitting there for three hours" to be burdensome. It is a further comment on the difficulty of defining, let alone measuring, fatigue that pilots accustomed to flying rigorous schedules requiring often eight to ten legs a day, sometimes far more, in and out of crowded terminal areas, found it fatiguing to suddenly be flying fewer, longer legs and spending most of the day at cruise.

Skills Maintenance and Erosion

Much has been said and written about the potential for automation to induce an erosion of manual flying skills, though the author can find no documented evidence for such a phenomenon. The dramatic term "automation atrophy" has been applied. The presumption is that pilots flying highly automatic aircraft will rely on these devices to the detriment of their flying skills, and when faced with the loss of automatic equipment, or transition to a less automatic plane, find themselves unable to do the job safely, or to conform to their own standards of performance. Similarly, the term "complacency" arises -- the presumption being that pilots operating with highly reliable equipment will become "complacent," probably meaning overly-trusting, inattentive, and accepting of lower levels of their own performance. One check captain commented, "I'm glad this equipment doesn't work right all of the time -- if it did, complacency would be a problem."

Some of the concern for "automation atrophy" has come from long-haul carriers, who have noted that senior copilots on advanced aircraft, who become ready for captaincy and must pass checkrides in less advanced aircraft, are experiencing difficulty. The long-haul aspect seems important, since these pilots have so few opportunities to practice critical maneuvers. This is in contrast with DC-9-80 operations, which are primarily short-haul (e.g. Hawaiian, PSA, and Air Cal), or medium haul (e.g. Republic east-west routes). The majority of Republic's trip pairings on the -80 call for four legs a day; some call for two and some three. Thus the typical -80 pilot might fly about 35-40 legs a month, possibly as many as 48. Obeying the custom of trading legs, each pilot could expect to make in the neighborhood of 20 takeoffs and landings a month. While this is far less than the experience of the typical DC-9 pilot at Republic, it is probably sufficient exposure to critical maneuvers to quell some of the fears of automation-induced skill loss. Nonetheless, some of the concern is based not only on a paucity of critical maneuvers, as in the long-haul carriers, but on simply over-reliance on automation regardless of the number of

terminal area and other critical operations. For the first two years of the -80 operations at Republic, the question was somewhat moot, as all but a handful of very senior captains and first officers flew mixed blocks. The -80 time was actually a minority of the flying experience. Thus the majority of the pilots had ample opportunity to retain their manual skills by flying traditional DC-9 aircraft.

In September 1983, a contractual change created a "separate status" for -80 crews. Under this change, crews would be exclusively assigned to the -80 for nine months, and would not be allowed to bid trips on traditional DC-9s during that period. Thus the skill loss question might have become more of an operational reality than it had been during the first two years of -80 experience.

To the extent that the experimental design permitted evaluating this question, there has been no indication of a problem with -80 pilots suffering skill loss. Prior to the separate status rule, there was little opportunity to examine skill loss induced by the -80, since nearly all of the pilots were also flying the traditional DC-9s. Even after the separate status had been in effect for nearly a year, there was no indication of an "automation atrophy."

Check captains reported that the six-month proficiency checks, which up until recently were flown in a -10 (PHX) and a -30 (MSP) simulator, were highly professional. Few pilots expressed any great concern over skill atrophy, as long as they continued to hand fly some on every trip, as it was typically stated. The check captains reported the same thing - they urged newly transitioned pilots to keep up their hand flying skills. The caution was hardly needed in the first 100 or so hours of flying the -80, as the typical response, reported to the author, was that when stress was encountered (e.g. unexpected ATC change in a terminal area; runway change; difficult SID) they would "click it off." This bears not only on the question of skill maintenance, but on skill acquisition as well. It is an interesting commentary that pilots so often reverted back to hand flying when the unexpected occurred. As one pilot put it, "I have never made an automatic go-around before, so when I get a go-around I'll do it the way I know how." (The automatic G/A is now a required maneuver in the -80 simulator training.)

Much of this difficulty in skill acquisition may have been induced by the lack of a -80 simulator, and this may have now changed since the arrival of Republic's simulator in May 1983. Furthermore, proficiency checks (PCs) for the -80 pilots are now flown in the -80 simulator in Atlanta. Soon after the arrival of the simulator, crews showed some apprehension about flying difficult maneuvers, such as engine outs, in the -80 on PCs, and the company decided to allow pilots scheduled for their six-month PC to take a "free ride" the day before in order to practice

maneuvers. This did much to allay their fears, and in addition was found by the simulator instructors to be a valuable training opportunity.

The response to Likert item No. 3 ("I am concerned about a possible loss of my flying skills with too much automation") received a mean response near dead-center in both waves, with a large standard deviation, indicating a wide range of responses from deep concern to no concern.

Concerning ground school methods, many crew members expressed a disappointment in their differences classes, and a feeling that they went into their initial operating experience (IOE) unprepared. Republic's ground school instructors made a genuine effort to make the most of the two days in the classroom to teach the -80 differences, and had added a "static airplane" session at night following the classroom periods. The static airplane consisted of an instructor and two students in the cockpit, with electrical power on the airplane, offering instruction in what they referred to as the "knobology," meaning essentially the location and actuation of the controls and switches. As a training device, the aircraft on the ground is extremely limited, as most of the crew actions would be non-interactive. The instructors did the best that could be done with the materials at hand, but were hampered by the obvious lack of a -80 simulator, as well as adequate (interactive) classroom training devices.

The flight guidance system and ATS of -80 do not lend themselves to static classroom training devices or media, of which slide/audio lectures are the most common. These are provided by Douglas for their customers, and may be as well executed as static training aids can be. But the main differences of the -80 are not the traditional systems (fuel, electrical, hydraulic etc.) which are suited to slide/audio presentation quite well, but the dynamics of the DFGS and ATS, which are not. What seems to be needed is higher quality, dynamic training devices, both for classroom instruction and auto-instruction. Microprocessor and high-resolution color displays are now within a reasonable price range, as well as interactive video disks, and other digitally based instructional devices. There appears to be a wide gulf in training devices between the elaborate high-fidelity (and high-cost) simulator at one end, and the slide show, paper trainer, and static classroom mockups at the other. Clearly there is a need for a research and development effort directed toward training devices and techniques to fill this gap.

System Reliability *

Attitude questionnaires show surprisingly little concern over the reliability of the automatic system in the -80. The three items (No. 25, 26, 28) dealing with reliability show a weak mean rejection of the negative statements, and a weak mean acceptance of the positive statement ("The new equipment is more reliable than the old").

Most of the concern centered around the digital flight guidance computer, and the A/T system. Most of those interviewed expressed some concern because they could relate at least one instance where the systems had failed to perform as expected. For example, many reported failure to capture a preselected altitude in climb or descent (the author observed one instance in a climb), failure to roll out on a preselected heading, or failure to capture a VOR or LOC beam. There was little complaint about glideslope tracking on an ILS, except the usual concern over porpoising, which seems to be an attribute of ground transmitters more than the on-board equipment.

Problems about aircraft failing to capture or departing from selected altitudes at level flight are harder to explain. It is worth noting that at the time of this writing, the Aviation Safety Reporting Systems (ASRS) has been receiving numerous incidents involving failure to capture altitudes from DC-9-80 crews. There is a very good chance that the departure was induced not by equipment failure, but by inadvertent actuation of the vertical speed knob, or even by a lack of understanding of its function. Several check captains reported that the trainees did not understand that once the preselected altitude capture had been annunciated in the FMA but prior to actual level-off, movement of the vertical speed wheel would cancel the capture and initiate vertical movement.

The typical problem was as follows: on a climb or descent at high vertical speed, altitude capture maneuver could begin and be annunciated over 1000 feet prior to the target altitude. An experienced DC-9 pilot, not accustomed to the fast climb and descent of the -80, would attempt to shallow out the maneuver after capture, but prior to completion of the pitch correction. (The flight guidance system does not obey the old rule of thumb of no more than 500 feet per minute vertical speed in the last 1000 feet.) This action would cancel the capture, and the crew may not notice the change in FMA annunciation. This problem reflects a lack of understanding of the role of the vertical

* Many of the negative comments about the flight guidance system were due to conditions that were corrected by the manufacturer in later models of the flight guidance computer.

speed wheel, the nature of the capture maneuver, and the role of the FMA messages when initiating a control selection or setup change. This illustrates only too well the importance of monitoring the FMA, a concern that appears frequently in interviews with check captains. Part of the problem may be that the changes in mode annunciation on the FMA are silent. Thus, capture can be cancelled, and very easily missed by the crews. Some pilots have recommended that an auditory alert be sounded whenever capture is cancelled. Others have recommended a more radical design change that would not allow a capture to be cancelled except by setting a new target altitude. Inadvertent cancellation of an altitude capture may be a problem that may vanish or at least be diminished as a result of increased -80 simulator training.

Much is said about the "unreliability" of the A/T system. The problem as described, and as pointed out to the author repeatedly in the cockpit, is probably not one of reliability -- the system rarely fails -- but of proper setting of gains. The 904 computer did much to relieve the instability problems, and later models such as the 907 and the 920 have resulted in steady improvements. Although the ATS instability was the target of much criticism, many pilots reported that the ATS was the feature of the -80 they liked the most, mainly its ability to control airspeed in climbout in a crowded terminal area and thus to relieve the pilots from monitoring airspeed. They seemed willing to live with the instabilities, since they could manage throttle control at cruise simply by allowing the ATS to set EPR to establish cruise Mach, and then turning the ATS off. This use of the equipment is consistent with the Wiener-Curry principles (Appendix 1) regarding designing automation to allow varieties of pilot options and styles.

Specific Features

Interviews and open-ended questionnaire items yielded valuable pilot opinion regarding not only automatic devices, but other cockpit features. Some of these are covered in great detail in Table 5, and in Section VI. Especially illuminating are the responses to the questions on what the pilots like most and least about the -80, compared to previous models of the DC-9. Let us examine just a few items, as they bear on the pilots' acceptance of the aircraft, and their perception of the workload level.

Many of the comments concerned what human factors engineers call control/display ratio, which is the number of units (usually linear or rotational) that a control must be moved per unit movement of the display. A low C/D ratio is a "sensitive" control. If it is too low, overshoot followed by fine-grain adjustment near the target value, result. If it is too high, excess course-grain actuation is required, which was the complaint here. There were frequent complaints about the C/D

ratio of the DH setting on the radio altimeter; the complaint being that it takes too many turns to change the setting from zero to 200 feet (the most frequent DH). The author tried it out recently, and found that the C/D ratio was 1 rev/40 feet (approximately). On trials performed by the author and a check pilot, it took about 21 seconds and about 26-28 twists of the knob to travel the full 500 feet allowable on the minimums window. This may not be a critical factor, but the pilots find it a nuisance, and as such contributes in some part to their perception of workload.

Similar complaints are heard about the ZFW setting, and the dial-a-flap wheel (especially stowing, as mentioned previously). One cannot say without some research what the optimal C/D ratio might be for these various instruments, nor is it critical to safety or operations. But the issue should not be dismissed as trivial if pilots are sufficiently annoyed by high C/D ratios to bring it up repeatedly in this study, and it is the very sort of small annoyance in the cockpit that leads to the sentiment that line pilots' opinions are not sought, and could prevent such design errors. Consistent with this, pilots praised the low C/D ratio on the CDI needle setting, and the instant response of the fuel counters to the zeroing button (as contrasted with older analog gauges, which required that the switch be held until the needles were driven to zero). Again, one should not infer that pilots are lazy, but only that they prefer sensitive controls that obtain the desired setting rapidly, especially since overshoot is not a serious matter in the instruments mentioned above. High C/D ratios are annoying to the pilot in the same way that even fractional second delays are annoying to computer terminal operators. The delays are trivial to system performance, but loom large in the minds of those who operate the equipment.

The strongest and most frequent complaint about cockpit design centered around the lighting, and in particular the necessity to bring up white flood lights to see the V-speed book at night. On every night flight the author took, one or both of the pilots discussed this, and demonstrated the lighting controls. Most felt that the lighting should have been left just as it was in the -50. It is difficult to understand why this did not show up in testing and certification.

Other cockpit features, such as the difficulty in seating the slat/ flap handle, and problems with inadvertent actuation of the vertical speed wheel in level flight at altitude select, have been mentioned. Numerous other complaints and praise can be found in Section VI.

The final persistent complaint was the fact that the pushbutton switches on the DFGS control panel do not self-illuminate when pushed (see Figure 5). It is true that one can not tell from looking which button (if any) had been punched, but

FLIGHT GUIDANCE CONTROL PANEL

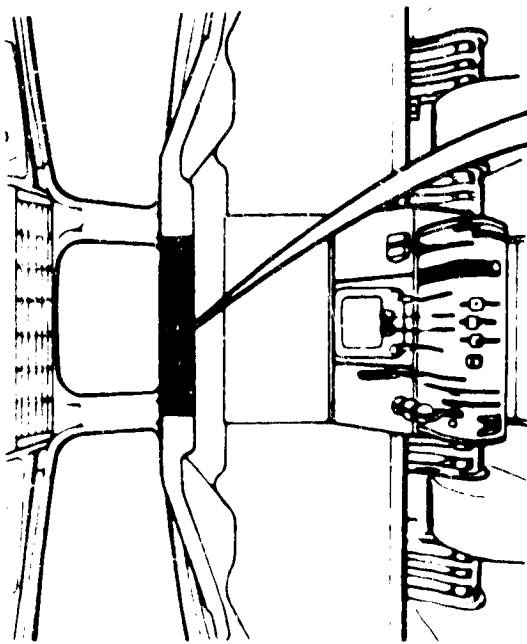
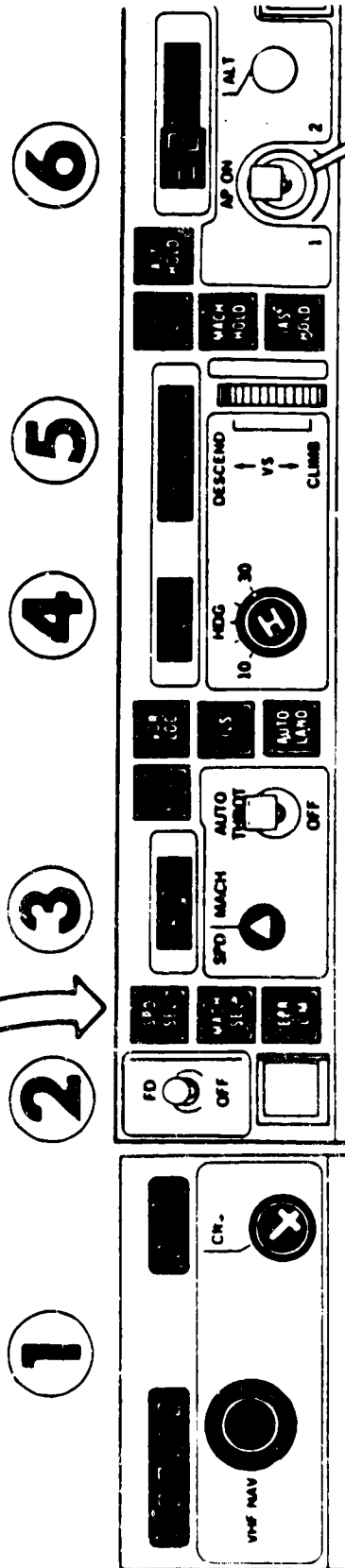


Figure 5



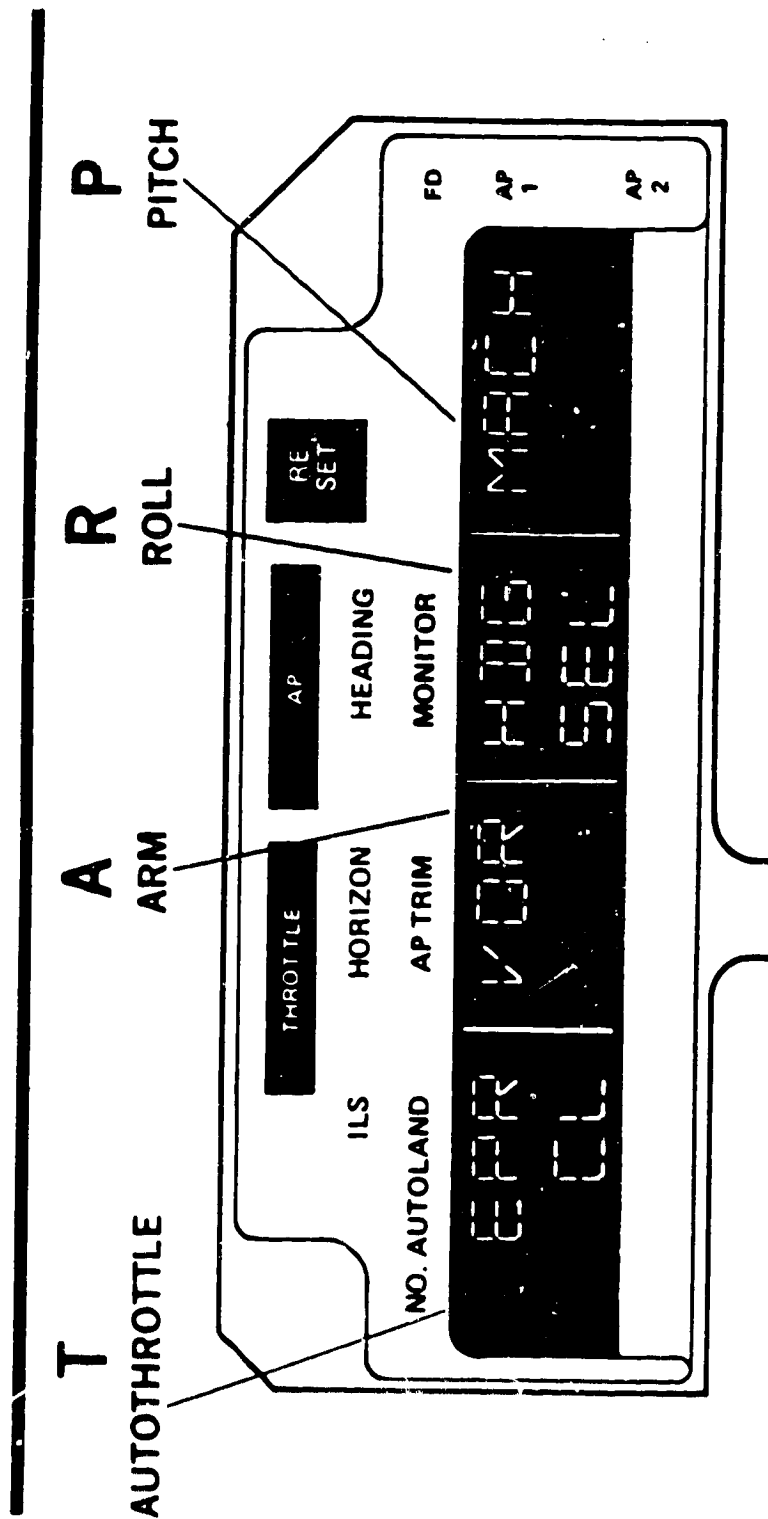
© MDC 1980

FCT DC-9-22-840040-38A

FLIGHT MODE ANNUNCIATOR (FMA)

Figure 6

ORIGINAL SOURCE IS
OF POOR QUALITY



of course that information is available from the FMA (see Figure 6). Generally a pilot would like to have information available at the source: a self-illuminating button allows a control to be also a display. On the other hand, one could imagine a design philosophy behind the non-self-indicating buttons that says that the FMA is the proper place to receive the information, and nothing should be allowed to be a substitute for FMA scanning. The author does not take sides in this. It seems a good researchable "knobology" question, and besides, it is not clear whether the self-illuminating switch was ever considered and rejected for the philosophical reason stated speculatively above, or simply was not considered.

In summary, it appears that in the view of the flight crews participating in this study, the generally excellent cockpit design of the -80 is marred somewhat by minor design errors which the crews find annoying. This may be inevitable, since there is seldom unanimity on design features. For example, the pilots interviewed were about evenly split on the absence in the -80 of an aural tone on the altitude alerter. At 750 feet prior to a preselected altitude, an amber light illuminates on the altimeter, and extinguishes at 250 feet prior. Older models of the DC-9 have a wide variety of altitude alerting devices and a variety of trigger points, but all include some form of aural warning. About half the pilots said good riddance, the tone was just one more annoyance in the cockpit. The other half felt that altitude "busts" were more likely with no aural reminder (except the CAWS voice warning after a 300 foot excursion). Even the check captains were divided on this issue, showing, if nothing else, that even pilots steeped in standardization are not a monolith. One can standardize procedures, but never pilot opinion. What is still not clear to the author is why 750 feet was chosen by the designer as the trigger point, in view of the customary 1000-to-go vocal callout from the PNF to the PF.

Psycho-social Factors

Many authors in the automation world, including Wiener and Curry (1980), have expressed concern (though have offered no evidence) that pilots in highly automated aircraft may some day suffer some sense of detachment or alienation from the flying job, engendered by a feeling that the job has become one of pushing buttons and not flying planes. To the knowledge of the author, the question has never been explored. The attitude scale items in Tables 2-A and 2-B offer a mixed picture. Scale Item 1 ("Flying today is more challenging than ever") received mild mean agreement (62) in both waves, but a large standard deviation so apparently there is rather varied opinion on this matter. Item 6 ("I think they've gone too far with automation") got a strong rejection, and Items 9 and 10, regarding looking forward to more automation in the future, received mixed opinions in both waves.

In the interviews the author detected no psycho-social symptoms such as job disenchantment, loss of self-esteem, or sense of detachment. None of the psycho-social items correlated significantly with total time (presumably a reflection of pilot age). Although there was talk of "being out of the loop", and references to automation as "Ataris" and "Pac-Man", this should be viewed as a minor frustration over adjusting to a new style of flight, and not a sign of deep-seated distress. In summary, the author encountered nothing in this study to warrant concern for psychological disenchantment with flying as a profession as a result of the advance of automation.

VIII. CONCLUSIONS

1. The DC-9-80 and its flight guidance system and other automatic features are generally viewed by the pilots who fly it as well conceived and well designed. While there are many features that are questioned and criticized by the crews, overall they hold the plane in high regard, and view it as a modern aircraft. Many questioned the economic value of the automation in the -80, and a few expressed the belief that in view of the economic conditions in the airline industry, they would have preferred that the -80 have the improved wing, the -217 engines, but essentially -50 avionics.

2. Crews generally responded favorably to abstract questions about flightdeck automation (aircraft type and model independent), but viewed increasing degrees of automation with mixtures of approval and apprehension. The overall view of automation was favorable, but many expressed concern about the pilot being "out of the loop," or "along for the ride." Many of the crew members, including the most enthusiastic, voiced a concern over the increasing degree of monitoring ("scanning") required by automatic equipment. Although pilot age was not a variable that was directly examined in the study, the interviews left the impression of at least a weak relationship between pilot age and acceptance of automation. Some of the senior captains were the most skeptical of the value and safety of increasing degrees of flightdeck automation, and the younger first officers tended to be the most enthusiastic. However, many of the older captains were strong supporters of increasing automation, and of the -80 avionics and flight guidance systems in particular. It is worthy of note that two captains reached mandatory retirement age (60) during the study, meaning that they had bid the -80 with only about two years left in their career. Both expressed the sentiment that they wanted to fly the most modern aircraft that they could before retirement.

3. There was overall a high usage of the automatic features, though the data indicated great variations in usage by individuals. The company policy which the crews call "we bought it, you use it" was questioned by many. A substantial number of pilots, particularly captains, felt that the automation should be provided by the company, but that it should be left to each individual to determine when and under what conditions he would choose to use or not use the automatic features. Many of the younger pilots were strongly supportive of the company policy. It is difficult to determine whether the less-than-total conformity to the company policy was based on skepticism about the automatic features and their reliability and functioning, or traditional pilots' insistence on their right to choose their own style of flight. Although company policy is outside of the scope of this report, the author notes that (1) the use of automatic devices may be more difficult to standardize than other cockpit

procedures; and (2) the Wiener-Curry principles (See Appendix 1) stress leaving the choice of automation to the pilot. Obviously this is a difficult question, which will require further line experience, and examination by researchers and flight managers.

4. During the initial period of this study, there was considerable concern voiced for the reliability of the automatic equipment, but by the second wave of data collection, which ended in August 1984, this concern had diminished. This was partly due to improvements in the equipment itself, for example, by that time a third generation of flight guidance computer (904) had been installed, and many of the previous problems had been eliminated. Also crews' initial apprehension about equipment reliability had diminished, and many came to realize that what they had initially viewed as equipment failures were actually crew errors in operation of the flight guidance system. By the end of the study, most crews felt that the equipment was highly reliable, and expressed only the concern that it required a degree of monitoring that was beyond what they had been accustomed to in the earlier DC-9s.

5. On the subject of workload reduction, there were mixed reviews, as the previous sections reveal. The attitude questions dealing with workload show an overall positive view, but in interviews the crews expressed the opinion that the workload reduction overall was slight, especially when "mental" ("cognitive") workload was taken into account, as well as the increased demand for monitoring. A consensus was that if one had to place a number on workload reduction, it would be around 15 per cent, far short of the expectations for the -80.

Specific pieces of equipment and certain procedures were seen as workload-increasing, for example the stab trim and CG procedure was viewed by the first officers as high workload items. Likewise for the operation of the dial-a-flap, especially in view of the perceived difficulty in seating the flap handle in the selected detent position, and the need to stow it after takeoff, which required a considerable number of turns of a rotary control. Individual features and design parameters were also criticized as workload increasing. For example, many crews were critical of the high control-display ratios (lack of sensitivity) in setting parameters such as the zero fuel weight, and the minimums on the radio altimeter, both rotary controls. Some of the strongest praise in connection with workload reduction was directed toward equipment that could not be described as automation, mostly notably the dual-head com radios. Nearly all pilots commented on the reduction in workload through the elimination of the need to write down communications frequencies.

There was considerable recognition of the fact that although workload may not have been reduced much overall, it was redistributed in a manner that allowed certain operations to be

performed at non-critical times (at the gate, for example) rather than during critical times such as second segment climb. Most often mentioned was the ability to program for SIDs at the gate, relieving the pilot of certain steps immediately after takeoff. Most often mentioned was the MUSEL-4 departure from Santa Ana (see Figure 4), which was a complex procedure, further complicated by a mandatory noise abatement power reduction at 1000 feet.

It is important to note once again that human factors engineers who have studied workload for years have not agreed on a definition, let alone a measurement, of workload. The author has side-stepped this question by simply defining workload as whatever the person doing the work says it is. Thus, while some of the comments and criticisms voiced by the crew may seem minor to the outsider (for example the number of turns necessary to set the radio altimeter minimums), they unquestionably affect the crews' perception of workload, and should not be ignored. The pilot who told the author that his workload had been increased because there was no place to put his pencil in the -80 must be taken seriously. (He stuck it between the glare shield and the bulkhead on traditional models.)

6. On the closely related issue of time for extra-cockpit scanning, pilots were almost unanimous in reporting that the automation and cockpit configuration of the -80 did not allow any additional time "to have your head out of the cockpit." Most attributed this to the increasing scanning or monitoring demand imposed by automation. This is a disappointing, though important finding, in view of the fact that flightdeck automation has been sold as a means of allowing crews to spend more time with extra-cockpit scanning, especially important for short and medium haul carriers whose crews spend a relatively large amount of their time in crowded terminal areas. Obviously the designers and operators will have to address this problem, as the forecast is for increases in terminal area traffic for the remainder of this century. If the results of this study are correct, advanced cockpit technology has not offered any relief.

7. In general, cockpit automation was not viewed, even by its strongest supporters, as a boon to safety. Their attitude toward the safety aspect of automation was essentially neutral. Most crew members viewed positively the fuel savings and workload redistribution properties of automation, and many simply praised the modernity of the -80 compared to earlier DC-9s, and many described it as a "neat" airplane to fly, but they saw no safety advantage to the automatic features.

8. This study did not provide a good test of questions relating to possible loss of proficiency due to over-reliance on automation. This was due primarily to the fact, already described, that during most of the study period, crews were flying mixed blocks of -80 and traditional DC-9 time, so we did not obtain good data on exclusive or nearly exclusive usage of

automation. It is interesting to note that most of the crews expressed concern over possible loss of proficiency, particularly prior to Republic's acquisition of the -80 simulator, when they had to anticipate taking a proficiency check in a -10 or -30 simulator. But none saw this as a serious problem, and each worked out his own "training program" of hand flying, which was seen as the means of avoiding any proficiency loss. Each had his own plan, which he stuck to religiously, almost as if it were a regulation. The author called these "personal FARs." Almost all reported that their programs had prevented any problem, and that they had encountered no difficulties in their proficiency checks.

The potential for proficiency loss in crews flying highly automated aircraft has been noted by airlines flying wide-body aircraft, especially in long overseas flights, and that the problem cannot be easily dismissed. This question is worthy of further research, and should be examined further in crews that are exclusively flying modern, highly automated aircraft. It is commendable that each crew member developed his "personal FAR," but the matter of skills maintenance may be too important to be left to each crew member's subjective judgement.

During the study, numerous -80 pilots bid back to traditional models of the DC-9. In Minneapolis, many had relatively little time in the -80, for reasons mentioned previously. But prior to the closing of the Las Vegas base, a group of -80 pilots with considerable time bid back to traditional models. All reported that the "backward transition" was no problem, and that within the first trip they were flying as well as ever. Some commented that their experience in the -80 had made them smoother pilots of traditional DC-9s after their backward transition.

9. The lack of a simulator during the first year and a half of operation of the -80 clearly hindered transition and training. Most crew members reported difficulty during their initial line experience. The duration reported varied considerably, but most felt that the first 100-200 hours were difficult. Some reported durations as little as 50 hours to "be comfortable" with the flight guidance systems. There was a clear difference between the Las Vegas crews who had taken their initial training in the -80 simulator program and the other pilots in the study with respect to their perception of the time required to feel that they had mastered the -80.

One problem that was probably underestimated in the -80 transition training was the performance differences between the models of the DC-9. The higher power, and greater rates of climb and descent of the -80, had not been taken into account in the training prior to the -80 simulator. Much of the difficulty that the -80 pilots encountered in operating the flight guidance system may have due in part to the higher performance of the aircraft. Many expressed surprise that they were "behind the

plane", and this exaggerated their initially awkward management of the flight guidance system and auto-throttles, and their feelings of not being "comfortable."

10. The establishment of the "separate status" agreement unquestionably aided in transition and proficiency acquisition and maintenance. It is not within the scope of this study to comment on labor-management agreements, but this case is an exception, as it so directly addresses a variety of human factors issues that were central to this study. It was clear from the comments of the Las Vegas pilots, who as a whole were the first to be impacted by the separate status, that transition was made considerably smoother by their ability to fly only the -80 during the initial period of exposure to the new cockpit. This is in contrast with the Minneapolis pilots, who often went months before acquiring 100 hours of experience in the -80. This view was strongly reinforced by the check airman interviewed by the author, both in Las Vegas and Minneapolis.

This is not to say that DC-9 pilots, especially those who were as experienced as those at Republic, cannot safely fly -80s and traditional models at the same time, but it is clear that transition time to the "comfortable" level is decreased, and probably total training time and certainly check airman costs are reduced by a separate status.

11. During Wave One, prior to the acquisition of the simulator, classroom training and the use of the static airplane for transition to the -80 was generally viewed as inadequate. The problem probably arises from the lack of proper instructional devices. The classroom presentations, both at Douglas' training center in Long Beach and at Republic's differences classes in Minneapolis relied on audio-visual (slide plus audio tape) presentation, and a static wooden mockup of the -80 flight guidance control panel. These devices are far from optimal for training for skill acquisition in managing a system as dynamic as the flight guidance system and auto-throttle system of the DC-9-80. Nor is an elaborate, expensive whole-task simulator the appropriate tool for initial familiarization and acquisition of programming skills. What is obviously needed is a family of dynamic, interactive training devices which are capable of demonstrating to the pilot trainee in real time the dynamics of the aircraft systems and the consequences of his actions.

Learning to control a new technology cockpit requires a new approach to training. It is inefficient to use an expensive whole-task simulator for training programming and cognitive skills. It is ineffective to do it with non-interactive (open-loop) devices. The time is ripe to develop new, cost-effective training techniques. The decreasing cost of computer hardware make such developments feasible, and they can probably be achieved with presently available off-the-shelf hardware. The cost and the challenge, however, remain in the area of training

methods and training software. It is a significant comment on training that the crews repeatedly told the author that whenever the slightest unexpected event occurred, such as a change of runway, they would "click it off."

12. Continuing attention must be directed toward basic human factors in the design of cockpits. The movement toward computer-based, new technology cockpits has made traditional human factors more important, not less. Programming errors, or what Wiener and Curry (1980) called "set-up" errors, remain a weak link in system management. Automated flight systems appear to have the disconcerting property of tuning out minor errors while making gross errors more likely (Wiener, 1985). While there is a lively discussion within the systems professions about the potential for new information technologies such as artificial intelligence to solve such problems, these techniques are undeveloped and unproven. At best, their introduction into the commercial cockpit may be years away. In the meantime, designers must pay careful attention to traditional problems, such as control design, keyboard entry devices, warning and alerting systems, and even such seemingly mundane matters as cockpit lighting. The effective employment of new technology on the flightdeck still depends to a large extent not on exotica, but on time-honored human factors principles.

13. This study has found no signs of automation-induced psychosocial problems such as negativity toward the flying as an occupation, or loss of self-esteem. It would appear that this is simply not a matter worthy of concern, and until early signs of such a problem appear in the future, further research into psychosocial areas does not appear to be justified. If any psychosocial effect was detected in the -80 pilots, it was a sense of pride in having the opportunity to fly a modern transport aircraft.

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1. This research was conducted under a Research Grant, No. NCC2-152, from the NASA-Ames Research Center to the University of Miami. The author was the Principal Investigator, and the Contract Technical Manager was originally Dr. Renwick E. Curry, later Dr. David C. Nagel. The author is indebted to Dr. John Lauber of NASA-Ames for a critical reading of the manuscript.

2. The male gender is used throughout this report, since all of the DC-9-80 pilots in the study are males. The term "Boeing" in this report refers to the 727-200. In 1983 McDonnell-Douglas redesignated the DC-9-80 as the MD-80. For consistency, the traditional designation is used throughout this report. The units of measurement in this report are in feet and miles, as appropriate to air navigation. For those wishing to convert to metric units, 1000 feet equals approximately 300 meters, and one mile equals approximately 1600 meters.

3. Apple II is a registered trademark of Apple Computer, and DB Master is a registered trademark of Stoneware, Inc. Visiterm and Visicalc are registered trademarks of Visicorp.

4. Figure 4 is reproduced with permission of Jeppesen-Sanderson, Inc. Figures 5 and 6 are reproduced with permission of Douglas Aircraft Corporation.

5. The following persons assisted the author at the University of Miami: Dorothy Dandes, Isabella Burgess, Sheila Mihoubi, Suelynn Hall, and Frank Sarfati. The management information system was designed and programmed by Ron Reisman.

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Capt. Mitch Griffin - LAS
Capt. Lynn Harpham - PHX
Capt. Tom Caswell - MIA

The real strength of the project came from participation of the line pilots, who volunteered to serve on the study panel, filled out questionnaires, and submitted to interviews. They are listed on the next page.

The following DC-9-80 check captains gave the author valuable information on training and transition of line pilots: Robert Mueller, Dick Ellis, John Maus, Wayne Fallon, Ray Kelly, Phil Soderlind, Jim Freeman, Louis Farrell, Russ Oberg, Mitch Griffin, Jack Brasher, and Phillip Lane. Some of those who were at one time check captains also volunteered as panel members.

The author is also grateful to McDonnell-Douglas and Air Cal for making it possible for him to attend DC-9-80 ground school in Long Beach in April 1981.

The author notes with regret the death of Capt. Robert Parranto, one of the original Minneapolis panel members.

PANEL MEMBERS

Minneapolis

Earl Adams
Bruce Beecroft
A. T. Bergum
Bill Boehne
Gordon Burgess
John Chambers
Stephen Cobb
Ward Conger
Raymond Domagala
John Ebert
Louis Farrell
Edgar Fischer
Randy Fogarty
James Freeman
Joel Harding
W. J. Hunchis
Richard Irgens
Brian Keegan
Brian Killmer
R. L. Knisely
John Knutson
Stanley Larson
R. G. MacDonald
Robert Marcue
Galen Marsh
Roger Miller
Jim Moser
Tom Norton
Mark O'Leary
Robert Parranto
Theodore Peterson
Steve Petrich
D. M. Pietro
Michael Robicneaux
James Sorenson
James Trumbell
Ernest Worthley
Wm. Scott Wright

Las Vegas

Harry Alton
Jack Brasher
James Campbell
H. C. Farrington
James Frazier
Ronald Klein
Phillip Lane
William Lea
Thomas Lee
R. L. Mansfield
Jim Martin
James Noelle
John Surbridge
Lee Tison

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XI. APPENDICES

- Appendix 1 Automation Principles from Wiener and Curry (1980)
- Appendix 2 Data management
- Appendix 3 Glossary of DC-9-80 terms and abbreviations
- Appendix 4 DC-9-80 automatic flight systems
- Appendix 5 Intercorrelation matrices of attitude data

Appendix 1

Automation Principles from Wiener and Curry (1980)

Control Tasks

1. System operation should be easily interpretable or understandable by the operator, to facilitate the detection of improper operation and to facilitate the diagnosis of malfunctions.
2. Design the automatic system to perform the task the way the user wants it done (consistent with other constraints such as safety); this may require user control of certain parameters, such as system gains (see Principle No. 5). Many users of automated systems find that the systems do not perform the function in the manner desired by the operator. For example, autopilots, especially older designs, have too much "wing waggle" for passenger comfort when tracking ground based navigation stations. Thus, many airline pilots do not use this feature, even when travelling coast-to-coast on non-stop flights.
3. Design the automation to prevent peak levels of task demand from becoming excessive (this may vary from operator to operator). System monitoring is not only a legitimate, but a necessary activity of the human operator; however, it generally takes second priority to other, event-driven tasks. Keeping task demand at reasonable levels will ensure available time for monitoring.
4. For most complex systems, it is very difficult for the computer to sense when the task demands on the operator are too high. Thus the operator must be trained and motivated to use automation as an additional resource (i.e. as a helper).
5. Desires and needs for automation will vary with operators, and with time for any one operator. Allow for different operator "styles" (choice of automation) when feasible.
6. Ensure that overall system performance will be insensitive to different options, or styles of operation. For example, the pilot may choose to have the autopilot either fly pilot-selected headings or track ground-based navigation stations.
7. Provide a means for checking the set-up and information input to automatic systems. Many automatic system failures have been and will continue to be due to set-up error, rather than hardware failures. The automatic system itself can check some of the set-up, but independent error-checking equipment/procedures should be provided when appropriate.

8. Extensive training is required for operators working with automated equipment, not only to ensure proper operation and set-up, but to impart a knowledge of correct operation (for anomaly detection) and malfunction procedures (for diagnosis and treatment).

Monitoring Tasks

9. Operators should be trained, motivated, and evaluated to monitor effectively.

10. If automation reduces task demands to low levels, provide meaningful duties to maintain operator involvement and resistance to distraction. Many others have recommended adding tasks, but it is extremely important that any additional duties be meaningful (not "make-work") and directed toward the primary task itself.

11. Keep false alarm rates within acceptable limits (recognize the behavioral impact of excessive false alarms).

12. Alarms with more than one mode, or more than one condition that can trigger the alarm for a mode, must clearly indicate which condition is responsible for the alarm display.

13. When response time is not critical, most operators will attempt to check the validity of the alarm. Provide information in a proper format for that this validity check can be made quickly and accurately and not become a source of distraction. Also provide the operator with information and controls to diagnose the automatic system and warning system operation. Some of these should be easy, quick checks of sensors and indicators (such as the familiar "press to test" for light bulbs); larger systems may require logic tests.

14. The format of the alarm should indicate the degree of emergency. Multiple levels of urgency of the same condition may be beneficial.

15. Devise training techniques and possible training hardware (including part- and whole-task simulators) to ensure that flight-crews are exposed to all forms of alerts and to many of the possible conditions of alerts, and that they understand how to deal with them.

Appendix 2

Data Management

(This section by Ron Reisman)

It was decided early in this project to do most of the basic data management tasks on the Apple II+ microcomputer, but to do the analysis of this data with sophisticated statistical software (SPSS) on a large mainframe computer (UNIVAC 1100) at the University of Miami. Thus we had to 1) assemble a versatile, fully supported management information system that would run on an Apple; and 2) devise a communications system so that the data could be easily accessed by relevant software packages on both micro- and mainframe computers.

DB Master, a commercial data base management program, was selected as the basis of the Apple's information system. The data from the questionnaires were entered into two DB Master files. One file contained the Likert data, the other file contained the Percent-Use data. Both files contained the flying time information about the individual pilots, along with several 'comment' fields for miscellaneous notations. A complete set of report formats were composed so that all data could be printed out easily. New report formats can be defined in the future.

DB Master uses a proprietary disk operating system (DOS) which is incompatible with the standard Apple disk operating system. A utility program, DB Master Utility Pak #1, is used to transfer the data from the DB Master files (which use the proprietary system) to disks using the standard Apple DOS 3.3. This utility translates the data from a DB Master format into a Data Interchange Format (DIF) which can be read by almost 100 other commercially available programs. Data which are stored in DIF can be sent to a variety of spread sheet, statistics, graphics or word processing packages. This provides the Apple-based management information system with considerable versatility, since a wide variety of packaged programs can be used to manipulate the data which was originally entered into DB Master.

In order to use the powerful, mainframe statistical analysis packages, the data had to be reformatted from the DIF files into a form more easily read by SPSS. A special program was written on the Apple which creates SPSS-compatible Likert and Percent-Use files from the DIF files and stores them on DOS 3.3 disks. These compatible files are then transmitted to the UNIVAC 1100 over telephone lines, using a modem (D.C. Hayes Micro-modem II) and communications software (Visiterm).

APPLE II

FORMS

DB MASTER
Data Management
Program

**DB MASTER
REPORT
FORMATS**



**LIKERT file
(DB MASTER
format)**

**PERC-USE file
(DB MASTER
format)**

**DB MASTER
UTILITY
PAC #1**

**LIKERT
file
(DIF format)**

**PERC-USE
file
(DIF format)**

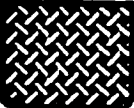
**DIF
compatible
applications
programs**

**DIF
CONVERSION
UTILITY**

**LIKERT
file
(SPSS format)**

**PERC-USE
file
(SPSS format)**

VISITERM



**LIKERT
file**

**PERC-USE
file**

**UNIVAC
1100**

SPSS



Appendix 3

Glossary of DC-9-80 terms and abbreviations

The following terms apply to the DC-9-80 systems. This glossary does not include common aviation terms and abbreviations. Many of the terms below are more fully defined in a glossary in the Republic Airlines' publication DC-9-80 Differences Training.

- ABS - Autobrake System
- ALFA Speed - minimum safe maneuvering speed for a given configuration
- ARTS - Automatic Reserve Thrust System
- ATS (also A/T) - Autothrottle System
- CADC - Central Air Data Computer
- CAWS - Central Aural Warning System
- CLAMP ("CLMP") - a mode displayed on the FMA when electrical power is removed from the autothrottle servos on takeoff roll
- Dial-a-Flap - a takeoff flap selector which allows the crew to select other than fixed detent positions
- DFGC - Digital Flight Guidance Computer
- DFGS - Digital Flight Guidance System
- FMA - Flight Mode Annunciator (see Figure 6)
- WARP - acronym for Thrust-Armed-Roll-Pitch, the four mode windows in the FMA. The term is sometimes used by pilots to mean the FMA itself.
- TCI - Thrust Computer Indicator (sometimes called TRI - Thrust Rating Indicator)

Appendix 4

DC-9-80 AUTOMATIC FLIGHT SYSTEMS

The following material is from the Republic Airlines Douglas DC-9-80 Pilot's Handbook. It is included for the benefit of the reader who may not be familiar with automatic flight, and is not intended to be a comprehensive description of the systems.

General

The airplane is equipped with a flight guidance system (FGS) for flight guidance throughout the entire flight envelope (takeoff to landing). Two digital flight guidance computers (DFGC 1 and 2) provide data input for the FGS functions.

Autopilot

The AP function, operating in conjunction with the yaw damper function, automatically controls the airplane in pitch, roll, and yaw maneuvering axes. Appropriate control surfaces are actuated by the AP to control the airplane for the selected mode of operation.

The AP modes of operation will automatically control the airplane pitch and roll attitude for the following maneuvers: maintain an existing altitude; descend or climb to and maintain a preselected heading, fly to, capture, and track a selected VOR or localizer course; capture and track a glideslope.

Autothrottle/Speed Control

The autothrottle/speed control functions are available for operation from takeoff to landing. Aerodynamic sensors, airplane surface transducers, CADC's, and other sources provide input to the DFGC's for speed control processing.

Seven throttle operational modes are available for selection on the FGCP and thrust rating indicator, or occur automatically. Selected speed modes are as follows: Indicated airspeed select (SPD SEL); Mach select (MACH SEL); and EPR limit for takeoff (TO), takeoff flexible (TO FLX), go-around (GA), maximum continuous thrust (MCT), climb (CL), and cruise (CR).

Appropriate annunciations including numerical values (when applicable) appear on the FMA (see Figure 6 of this report) to indicate existing operating mode of the autothrottle/speed control.

The autothrottle function automatically positions the throttles to maintain airspeed or engine thrust as require for the operational mode selected and airplane control surface configuration. The autothrottle function will control the throttles for the following maneuvers: Takeoff, climb, cruise, holding, approach, flare, and go-around.

Altitude Advisory System

The altitude advisory system automatically alerts the Captain and First Officer that the airplane is approaching the preselected altitude or that the airplane is deviating from a previously selected and acquired altitude. An advisory light on each altimeter provides the alert for either of the above situations.

Autobrake

When set, the automatic brake system (ABS) will automatically apply brakes during landing and takeoff modes of flight. The ABS landing mode is armed prior to landing after landing gear is extended.

Appendix 5

Intercorrelation matrices of attitude (Likert scale) data

ORIGINAL PAGE
OF POOR QUALITY

WAVE ONE

TT	TT	PEARSON CORRELATION	COEFFICIENTS	L3	L4	L5	L6	L7
L1	1.0000	.2294	-.0076	.0633	2.044	.0261	1.001	.6013**
L2	.2294	1.0000	.2815	.0456	-.6907	.0250	.1777	.4370*
L3	.0076	-.2815	1.0000	.0466	-.0907	.0250	.1777	-.4383*
L4	.0456	.0907	-.0466	1.0000	-.5144**	.1901	-.0600	-.0938
L5	.0466	-.0907	.0466	.5144**	1.0000	.0211	.0002	.4779*
L6	.0907	.0250	-.0466	1.0000	-.1649	.0211	.0000	.2696
L7	.0250	-.0250	.0466	-.0600	.0002	.1649	.1741	-.0476
L8	.0476	.4470*	-.0938	-.0938	.2471	.0543	.5050**	.1615
L9	.0459	-.4383*	.1901	.1901	-.4779*	.1741	.0564	.1000
L10	.0359	-.0590	.1737	.2658	-.0456	.0500**	.3195	.0000
L11	.2838	.3164	-.2572	.2946	-.0976	.1316	.3195	.0033
L12	.0140	.3481	.0627	-.3368	-.2722	.0442	.7563**	-.3333
L13	.0063	.2630	.0771	.1501	-.2744	-.2445	.7336**	-.1068
L14	.1728	.2983	-.0638	.1534	-.2375	-.0906	.4752*	-.2565
L15	.5257**	-.1744	.1281	.1365	-.2013	.0895	-.0328	-.1686
L16	.2867	.2419	-.2850	.2240	.1967	.5013**	.2111	.2892
L17	.3393	.3393	.1691	.0671	-.2927	.0646	.5042**	.1697
L18	-.0163	-.4022*	-.2372	.3236	.5948**	.1934	.2193	.7931**
L19	-.3530	1.001	.2647	.3639	.1375	.2055	.0478	.0829
L20	.0649	-.0899	-.1935	.2246	.4265*	.2376	.4868*	-.1820
L21	.1940	.3367	.1634	-.2321	-.3135	.4092*	.4987**	.2953
L22	.1412	.2817	-.0159	.0924	.2803	.4243*	.4688*	.4439*
L23	-.0122	-.2226	-.0672	.0942	.2519	.5675**	.5552**	.6543**
L24	.0236	.3739	-.0305	-.0900	-.4746*	.0659	.0293*	.3485
L25	.1759	.0921	-.0397	.1131	.0316	-.2969	.0115	-.0743
L26	.2371	-.4063*	.0493	.1633	.3238	.0056	.5628**	.4298*
L27	-.0732	.1444	.0883	-.2261	.1777	.3673*	.1903	.3771
L28	-.1065	.4538*	.0506	.2437	.4165*	.1556	.8633**	.3409
L29	-.0591	-.3512	.1700	.2943	.3397	.2422	.0165	.3120
L30	.0599	.4336*	-.1309	-.1362	-.4172*	.1909	.0208	.3026
L31	.2106	.2946	.0311	.2833	-.4151*	-.0392	.2114	.1521
L32	.0640	-.2536	-.0444	-.1819	.0894	.4022*	.0628	.2603
L33	-.0517	.3778	.0841	.1415	-.4498*	-.0806	.0239*	.1146
L34	.2835	.2463*	.0592	-.1522	-.2793	.2169	.4698*	.3780
L35	-.4104*	-.1218	.0515	-.0796	-.0539	.0153	.2646	.1831
L36	.1552	.402*	-.0864	.0900	-.1671	.1276	.1288	.3884*
L37	.4728*	-.4247*	.0373	-.1179	-.3936*	-.2420	.9406	.2751
L38	-.0893	.4247*	.1275	-.2763	-.4294*	.1327	-.0300	.2225
L39	.0971	.3761	-.1640	.1056	.0721	-.1061	.0860	.2566

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COEFFICIENTS
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	L6	L9	L10	L11	L12	L13	L14	L15	L16	L17
TT	.2839	.0140	.0063	.1726	.5257**	.2657	.2621	.0163	.3530	.0649
T60	.3164	.3491	.2630	.2963	.1744	.2418	.3395	.4022*	.1001	.0699
DAYS	.2572	.0627	.0771	.0636	.1261	.2850	.1691	.2372	.2847	.1985
L1	.2986	.1107	.1501	.1534	.1540	.2240	.0671	.3236	.3639	.2246
L2	.0976	.3368	.2744	.2675	.2016	.1667	.2927	.5948**	.1375	.4265*
L3	.1638	.2579	.3159	.0908	.1665	.5710**	.0503	.1934	.0430	.2890
L4	.1315	.2744	.2445	.1675	.0695	.5013**	.0646	.2193	.2055	.2378
L5	.0309	.0442	.0272	.0951	.3033	.2851	.1253	.0476	.1158	.2282
L6	.3487	.7363**	.7336**	.4752*	.0328	.2111	.5042**	.7531**	.0629	.4668*
L7	.0033	.2333	.1668	.2505	.1666	.2652	.1697	.5674**	.1820	.3673
L8	1.0000	.5189**	.4662*	.0111	.1580	.3195	.3385	.1753	.0878	.0342
L9	.5189**	1.0000	.9355**	.4058*	.0981	.2868	.4524*	.6811**	.2780	.3509
L10	.4662*	.9355**	1.0000	.4663*	.0644	.2385	.4176*	.5178**	.0804	.2350
L11	.0111	.4663*	1.0000	1.0000	.0644	.2385	.4176*	.5178**	.0804	.2350
L12	.1580	.0644	.0644	.0644	.0981	.2868	.4524*	.6811**	.2780	.3509
L13	.3195	.2385	.2385	.2385	.2336	1.0000	.0750	.4279*	.2608	.0477
L14	.3369	.4825*	.4524*	.4175*	.1303	1.0000	1.0000	.5341**	.0082	.2855
L15	.1793	.6482**	.6811**	.5178**	.1171	.4279*	.0082	1.0000	.1493	.5799**
L16	.0679	.2780	.2990	.0604	.6983**	.2608	.0022	.1493	1.0000	.2038
L17	.0342	.3509	.3531	.2350	.0477	.2190	.2855	.6759**	.2036	1.0000
L18	.0452	.3461	.3231	.3877*	.0869	.4308*	.3050	.5250**	.0587	.4363*
L19	.1582	.4898**	.4750**	.3811	.3135	.3008	.1163	.4787*	.2654	.2982
L20	.0600	.5286**	.4980**	.4284*	.0633	.3720**	.1796	.5701**	.1956	.4551*
L21	.1228	.5535**	.4648*	.6331**	.1007	.2300	.0022	.5895**	.1501	.2672
L22	.0643	.3710	.3980*	.3915*	.2373	.1445	.2545	.2839	.0752	.3053
L23	.1071	.4717*	.4313*	.2239	.1800	.1817	.3197	.6737**	.2017	.4266*
L24	.0202	.3933*	.3401	.1959	.0075	.1595	.1627	.3117	.3357	.4266*
L25	.1674	.5843**	.5118**	.3223	.1612	.1631	.2690	.6334**	.0182	.6110**
L26	.2306	.3468	.2950	.0765	.2193	.1040	.1670	.4662*	.0895	.4239*
L27	.2616	.5924**	.5656**	.4726*	.0543	.0674	.4252*	.6848**	.0134	.6715**
L28	.0851	.3164	.3054	.3019	.2172	.0701	.4344*	.6363**	.1183	.4541*
L29	.2198	.3787**	.7126**	.3262	.0013	.3290	.4383*	.6213**	.2814	.4810**
L30	.3927*	.5853**	.5306**	.3345	.0792	.0013	.4439*	.5895**	.2539	.5470**
L31	.1295	.2376	.2935	.4508*	.0234	.0467	.3412	.5157**	.2267	.4267*
L32	.1381	.0164	.0371	.1330	.0773	.0773	.2506	.0833	.2128	.1709
L33	.4654*	.4970**	.5756**	.4577*	.0925	.1371	.3957*	.6395**	.0382	.2377
L34	.2482	.4998**	.3885*	.3386	.0816	.1599	.4975**	.5703**	.0360	.4709*
L35	.3678	.6353**	.5434**	.1605	.1078	.2072	.4629*	.5104**	.2075	.4342*
L36	.3532	.5347**	.4953**	.5266**	.1537	.1364	.5973*	.3894*	.0224	.0287

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	L18	L19	L20	L21	L22	L23	L24	L25	L26	L27
TT	1940	1412	0122	0236	1759	2371	0332	1066	0591	0592
T80	3367	2917	2225	3735	921	4063*	1444	4058*	3512	4338*
DA1'S	1034	0155	0872	0305	0397	0397	0983	0506	1700	1209
L1	2531	9884	3942	0900	1151	1633	2261	2437	2843	1852
L2	2021	2608	3498	4746*	0316	0236	0014	4165*	3397	4172*
L3	3133	0008	3498	0665	1726	0056	1777	3171	2462	1809
L4	4092*	4243*	3473**	1825	2963	1746	3973*	3553	2889	1987
L5	9867	1825	0259	0115	0259	1367	0585	0897	0185	0208
L6	4987**	4558*	5533**	5769**	2003	5626**	0585	6963**	5488**	6469**
L7	2953	4439*	5363**	3435	0743	4298*	3771	3405	3120	3320
L8	0452	1362	0660	1226	0643	1071	0202	1674	2306	2618
L9	5461	4886*	5286**	5535**	3716	4717*	3933*	5643**	3455	5924**
L10	3231	4750*	4940**	4648*	3980*	4313*	3401	5118**	2850	5658**
L11	3877*	3611	4264*	6331**	3916*	2239	1859	3223	0765	4726*
L12	0869	3135	0632	1007	2073	1600	0075	1612	2193	0843
L13	4308*	3008	5720**	2300	1445	1817	1905	1091	1040	0674
L14	3050	1183	1798	6036**	2545	3197	1627	2960	1870	4252*
L15	5220**	4787*	5761**	5895**	2839	5737**	3177	6334**	4662*	6848**
L16	0587	2651	1955	1501	0752	2017	3337	0152	0693	0134
L17	4365*	2982	6152**	3096	1447	3055	4266*	6110**	4239*	6715**
L18	10000	3871	6496**	2745	2447	5967**	2975	3339**	4246*	5440**
L19	3371	0000	3940*	10000	4563*	3447	4043*	3419	2225	5169**
L20	6153**	6496**	3940*	10000	4563*	3447	4043*	6793**	3723	4936*
L21	3096	2745	3824	5383*	10000	2076	4865*	4063*	2918	3662*
L22	1447	244*	3624	5383*	10000	10000	3041	3423	4013*	3604
L23	0367	3967**	3447	3426	2076	10000	10000	4029*	2756	4374*
L24	2975	8043*	4811*	2524	4865*	3041	4029*	10000	7560**	6496**
L25	5339**	3416	6783**	4385*	3126	3422	2758	10000	5191**	5191**
L26	4246*	2225	5194**	3723	2516	5013*	4374*	6496**	5191**	10000
L27	5440**	5189**	4936*	5596**	3882*	3604	4374*	7410**	6637**	5939**
L28	5449**	2639	4936*	5004**	3138	3604	4374*	5618**	3634*	5471**
L29	4654*	4678*	3240	3660	2772	4238*	4402*	5149**	4766*	6592**
L30	408*	3405	2337	6657**	3450	3473	2819	3994*	2661	3926*
L31	4358*	1530	4034*	4034*	0021	0814	0003	3994*	0648	1567
L32	1643	1387	0118	4034*	0754	0474	1413	3711	2715	422*
L33	2690	2632	4039*	3992*	3776	3266*	1493	3711	2715	422*
L34	4914*	3626	5035**	5041**	6979	3314	4276*	5696**	4710*	5565**
L35	3827	3987*	5446**	4415*	0936	3107	4210*	6072**	4654*	5950**
L36	3311	4276*	4731*	5463**	4702*	2493	3167	2847	2375	4534*

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	PEARSON CORRELATION			COEFFICIENTS		
	L29	L30	L31	L32	L33	L34
L1	2106	0640	2635	-4104*	2512	1852
L2	2946	-2036	4463*	1218	4002*	4278*
L3	0311	0641	0592	0616	0864	0873
L4	-2858	-1415	1322	-0796	0900	-1179
L5	4151*	-0894	-2793	0539	1671	-3936*
L6	-2020	3889*	-0806	0058	1276	-2420
L7	0382	4022*	2169	0231	1648	-1327
L8	2114	0899	4596*	2648	1289	0300
L9	-5869**	5643**	-3780	0489	-4734*	5570**
L10	1621	-2803	1931	1205	2791	-2225
L11	0861	-2198	1295	1381	4034	3678
L12	3184	-6787**	2375*	0184	4970**	6353**
L13	3054	-7126**	2935	-0371	5756**	8434**
L14	3019	3262	4508*	1330	4577*	1605
L15	-2172	0013	0234	2565	-0925	1078
L16	-0701	3230	0487	-0773	1371	-1595
L17	4344*	-4583**	3412	-2506	3957*	4829*
L18	-5363**	5213**	-5157**	0553	-6333**	-5104**
L19	1188	-2814	0856	2128	0382	-0360
L20	4541*	4910*	-2267	-1709	2377	-4542*
L21	2639	4678*	4358*	-0796	2632	3828
L22	-5188**	5938**	2337	0118	3992*	-5093**
L23	3136	-2772	4044*	1367	3776	0970
L24	-2132	4238*	0021	-0754	3266	-3514
L25	3210	4402*	0914	-0474	-3266	-4210*
L26	-7410**	5618**	-0003	1413	1463	-6072**
L27	-6837**	3834*	-3894*	0353	3711	-5696**
L28	6935**	-5471**	2661	-0646	-2713	4654*
L29	10000	3651	3926*	1587	4222*	5950**
L30	-3651	10000	4674*	-0932	2678	6243**
L31	4674*	-4026*	1927	1089	-4232*	4822*
L32	-0932	4026*	10000	0977	4026*	4727*
L33	2678	-4232*	0977	10000	4658*	3098
L34	6243**	4566*	4658*	4136*	0613	0518
L35	4822*	6555**	3471	0613	10000	6531**
L36	2384	-5537**	2003	-0585	4511*	3995*

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WAVE TWO

TT	T90	PEARSON	CORRELATION	COEFFICIENTS	L5	L6	L7			
	DAYS	L1	L2	L3	L4	L5	L6			
L8	1.0000	0.811	0.505	-0.084	1.780	0.597	0.203	1.522	0.3974	0.320
L9	0.811	1.0000	-0.315	0.309	1.915	2.942	4.130	3.579	1.311	0.321
L10	0.505	-0.315	1.0000	0.724	1.535	3.359	2.747	1.011	1.847	0.323
L11	0.811	0.309	0.724	1.0000	3.313	0.278	-1.772	-1.087	0.808	-0.371
L12	1.780	1.915	1.535	3.313	1.0000	4.677	3.540	1.746	0.203	0.203
L13	0.309	0.278	0.359	0.278	4.677	1.0000	4.490	4.490	1.741	1.741
L14	2.942	4.140	-2.747	-1.772	2.433	3.940	1.0000	7.307**	3.406	3.406
L15	1.535	3.359	-1.011	-1.087	3.416*	4.490	1.0000	1.126	1.343	1.343
L16	3.313	0.278	3.547	0.906	1.746	4.340	1.0000	1.126	4.930	4.930
L17	0.309	0.278	0.359	-0.371	0.203	1.741	4.340	1.126	1.343	1.343
L18	1.780	1.915	1.535	3.296	0.203	0.344	1.019	1.788	0.850	0.850
L19	0.309	0.278	0.359	3.296	0.203	3.053	5.427*	2.553	4.924	4.924
L20	1.780	1.915	1.535	4.817	0.646	4.463	4.463	3.831	5.978*	5.978*
L21	0.309	0.278	0.359	4.817	0.646	0.354	3.116	-3.624	4.241	4.241
L22	2.942	4.140	-2.747	3.747	1.318	3.471	1.481	3.526	0.174	0.174
L23	1.535	3.359	-1.011	-2.628	3.944	7.993**	6.593**	2.480	1.902	1.902
L24	3.313	0.278	3.547	1.460	1.416	0.573	3.597	2.480	1.379	1.379
L25	0.309	0.278	0.359	3.616	4.260	1.670	0.276	2.234	2.998	2.998
L26	1.780	1.915	1.535	4.349	1.416	1.146	0.368	1.230	1.614	1.614
L27	0.309	0.278	0.359	3.616	6.896**	4.209	3.122	6.262*	2.837	2.837
L28	2.942	4.140	-2.747	1.460	1.971	3.578	4.439	2.868	2.400	2.400
L29	1.535	3.359	-1.011	2.786	2.786	3.526	0.895	1.111	5.266*	5.266*
L30	3.313	0.278	3.547	3.156	3.889	4.526	3.599	3.782	8.447*	8.447*
L31	0.309	0.278	0.359	2.647	3.889	1.135	-3.460	-1.127	4.479	4.479
L32	1.780	1.915	1.535	2.489	0.795	4.807	2.941	1.664	5.502*	5.502*
L33	0.309	0.278	0.359	2.518	5.019	5.391*	2.694	3.608	2.808	2.808
L34	2.942	4.140	-2.747	0.127	0.653	2.888	4.443	3.745	2.916	2.916
L35	1.535	3.359	-1.011	0.732	0.814	4.811	0.372	0.634	8.759**	8.759**
L36	3.313	0.278	3.547	0.264	1.479	4.096	1.926	2.040	0.651*	0.651*
L37	0.309	0.278	0.359	0.264	0.487	2.142	1.325	0.635	4.644	4.644
L38	2.942	4.140	-2.747	0.171	-0.260	0.576	1.257	0.401	3.080	3.080
L39	1.535	3.359	-1.011	-2.153	1.533	5.033	0.411*	3.648	4.204	4.204
L40	3.313	0.278	3.547	0.362	3.007	4.596	0.447	1.859	0.300	0.300
L41	0.309	0.278	0.359	0.793	3.622	2.438	1.602	3.368	2.607	2.607
L42	1.780	1.915	1.535	-1.724	1.820	3.141	4.873	4.399	2.650	2.650
L43	0.309	0.278	0.359	0.890	0.929	4.478	-3.293	-0.393	3.081	3.081
L44	2.942	4.140	-2.747	2.228	-2.925	-5.140	-1.749	-1.794	4.477	4.477
L45	1.535	3.359	-1.011	3.816	-0.397	-4.065	-4.371	-2.733	4.291	4.291
L46	3.313	0.278	3.547	3.863	3.210	0.433	-3.613*	-1.383	-3.991	-3.991

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** - SIGNIF. LE .01
* - SIGNIF. LE .05

	PEARSON CORRELATION COEFFICIENTS									
	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17
TT	1434	1318	0633	0253	3827	2504	0049	-2056	-2690	2242
T80	3247	1086	1897	2441	241	5037	1835	1257	3720	-0781
DAYS	0045	0355	0251	2542	2030	0855	1670	2977	1748	3237
L1	2002	3296	4817	4483	3747	-2528	3811	3911	4348	0720
L2	-2846	0021	0648	-0795	1316	3944	1953	4260	1416	6886**
L3	-0344	-3053	4463	-0514	3471	7395**	0573	1670	1147	4808
L4	1019	5427*	4485	-3116	1491	7596**	3597	0276	0388	3122
L5	-1788	-2555	-3831	-3624	3526	6059*	2480	2234	-1230	5262*
L6	1021	4924	5978*	4241	0174	1902	-1379	2989	1614	2887
L7	0850	2601	3798	3876	0803	2682	0930	0930	1614	2887
L8	10000	2607	3157	2664	2763	0505	0295	0738	1885	-3134
L9	2607	10000	7818**	6416*	1746	4252	5720*	0135	2416	1882
L10	3157	7818**	10000	7232**	3628	4690	3426	1601	3498	-2023
L11	2884	5416*	7232**	10000	2119	2003	6206*	2041	2694	-2317
L12	2763	1746	2119	2119	10000	2716	1112	0561	2694	-4555
L13	0503	-4252	-2003	-2003	2716	10000	1112	0710	0810	3143
L14	2295	5720*	3426	6206*	1254	1112	10000	2988	0107	3054
L15	0738	0135	1801	2041	0561	0710	2988	10000	0160	4738
L16	1986	2416	3496	2694	6855**	0810	0107	0160	10000	2736
L17	-3134	1882	2023	2317	4555	4201	3143	4738	2736	10000
L18	0114	6729*	7405**	3607	1417	0726	-4735	4814	2005	0114
L19	1144	-3929	-2513	3690	1524	4537	-1166	5145	0437	4619
L20	1829	4382	3743	3342	1524	1636	4212	0212	1794	3526
L21	1696	5254	5559*	4574	0483	4269	1703	1390	0366	0666
L22	0529	6513*	7790**	4364	0623	4469	4076	4086	1633	3471
L23	0092	5164*	4138	3150	1603	3775	2152	0472	2126	1903
L24	0333	1211	3366	1119	2338	2730	0900	3094	1473	1700
L25	2539	-2307	3261	1377	0508	2730	0672	0731	3134	1398
L26	1421	1872	2909	0342	1793	3261	0672	0731	3134	1398
L27	1841	4865	3417	4861	3727	0722	4342	5821*	3592	-3788
L28	-2686	4179	2683	4789	1046	0018	6151*	2659	1393	3336
L29	2034	6368*	7099**	4342	2274	5461*	3417	0184	0316	3143
L30	1342	2571	0805	4342	0114	3701	4720	0184	0316	3143
L31	1688	0048	0595	247*	1934	3701	3291	3291	3076	-1546
L32	1668	3846	2279	3039	2715	1428	2009	3934	0738	1752
L33	1953	2144	4173	3362	2619	4252	3818	2865	3636	1575
L34	4305	-969	4173	1362	4777	4252	1188	1485	1235	-0491
L35	4419	6015*	5658*	3830	3795	3127	1902	-0025	2563	-6263*
L36	0551	5939*	5550*	4504	3795	3127	3726	-0177	2821	-4857
			5200*	4772	6519	3614	2610	-0819	2392	1415

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** - SIGNIF. LE .001

	L18	L19	L20	L21	L22	L23	L24	L25	L26	L27
FT	-1715	1688	-1134	-0536	2122	0430	-0300	-1240	0659	0719
L60	-1502	0864	1699	-1444	-1444	3530	-1276	4354	3214	3214
DAYS	0651	3856*	-0232	-1301	0436	1802	-2901	1826	1055	-4122
L1	3616	1400	-0577	2647	2489	2618	-0127	0732	0753	0264
L2	1971	2286	3136	3889	0796	5019	0663	0814	1478	0497
L3	-3578	3526	4526	-1185	-4807	5391*	2898	4811	4886	-2142
L4	-4439	0855	-3460	-3460	-2941	2634	4443	5372	1925	-1325
L5	2868	1111	3782	-1127	-1664	3638	3745	0834	2040	-0635
L6	-2400	5266*	5447*	-4479	-5502*	2808	2916	6752**	5551*	4644
L7	-1023	1727	2047	-4304	-3247	1372	1709	3644	5851	-2142
L8	-0114	1144	1628	-1636	0529	0032	0330	2839	1421	1641
L9	8729*	-3929*	1628	5254	6515*	-5164*	-1211	-2307	-1872	4965
L10	7405**	-2513	-3743	5539*	7790**	-4138	-3366	-3261	-2909	3417
L11	3607	3690	-3042	4574	4364	-3150	-1112	-1377	-0342	4661
L12	2565	-1417	-1524	0493	0625	-1603	-2338	3508	1793	3727
L13	-4201	0726	4537	-1636	-4269	4463	3770	2730	0672	-0722
L14	1522	4735	-1166	-4212	1703	-4076	-2152	0900	0672	4342
L15	4432	4914	5145	-0212	1390	4096	0472	3094	0731	-5821*
L16	2005	-0437	-1794	1581	-0365	1633	-2126	1473	3134	3592
L17	-0114	4619	3526	0448	0666	3471	1923	1700	1386	-3786
L18	10900	-0057	-0563	6111*	7165**	-2350	-3492	-2067	-1784	0858
L19	-0057	10000	3572	-0805	-1677	-5190*	-1375	4511	3232	-3070
L20	-0583	3572	10000	-0813	-3516	4613	1762	3301*	4750	-3708
L21	6111*	-3608	-0613	10000	6078*	-2837	-2672	-3847	-2082	4219
L22	7165**	-1877	-3616	6078*	10000	-5749*	-4714	-3119	-3119	1266
L23	-2880	8190*	4613	-2237	8749*	10000	1600	3128	1608	-2821
L24	-3492	-1375	1769	-2672	4714	1608	10000	0828	-0803	0261
L25	-2067	4511	5901*	-3947	-4763	3126	0628	10000	-6558*	-2568
L26	-1784	3232	4750	-2082	-3119	1808	-0803	8536**	10000	-0675
L27	0859	-5070	-3708	4219	1266	-2591	0281	-2591	-3675	10000
L28	3217	5205*	-2467	5220	1471	-2324	1475	-3123	-1761	4209
L29	-5754*	3559	2018	-5755*	-7181**	5641*	3650	4800	3837	-2755
L30	-0590	-1442	0713	2600	-1967	0645	2063	1131	6292*	6170*
L31	2661	1144	-1965	1614	-1174	2365	1487	1915	-0379	5170*
L32	3507	-2160	4180	-2766	-3587	2367	0599	3645	4403	-1020
L33	4465	0282	1274	2289	4317	-1304	-3933	-2519	-2354	2271
L34	4332	4064	-1172	2988	4150	-2131	-1528	-3649	2975	2945
L35	4790	-3377	-1362	5450	3237	-0694	-0208	-2898	-3161	5482*
L36	2944	0923	-2260	5836*	4902	-0810	-5142	-0750	0136	3749

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ORIGINAL PAGE
OF FOUR

	L28	L29	L30	L31	L32	L33	L34	L35	L36
TT	279A	2181	0377	3488	-4120	-0387	-2144	-1589	0484
L80	0077	2800	0339	1936	3058	0562	2228	1391	0185
DAYS	2536	0628	0340	0940	0204	1629	-4231	-3068	2674
L1	0171	-2153	0362	0790	-1724	0890	3475	3816	3883
L2	0260	1533	3007	0790	1920	0929	-2925	-0397	3210
L3	0576	5033	4596	2438	3141	4476	-5140	-4065	-0443
L4	1257	5411*	0447	1602	4573	-3293	-1749	-4371	-5613*
L5	0401	3646	1659	3866	4399	-0323	-1794	-2733	-1385
L6	3060	4204	0300	-2607	2650	3051	-4477	-4291	-3991
L7	1121	3657	1312	-2896	1434	-3165	0316	-1911	-5349*
L8	2686	2034	1342	-1688	1668	1955	4305	4418	0551
L9	4179	6368*	2571	-0048	3845	2144	3968	6015*	5938*
L10	2683	-7099**	0805	-0595	-2279	-4173	5698*	5550*	5200*
L11	4789	4342	2479	1985	3039	1362	3630	4004	4772
L12	1046	-2274	-0114	-1934	2715	2619	4777	3785	0519
L13	0016	5461*	3701	1428	3930	-4252	-3121	-3165	-3614
L14	6151*	3417	4720	2009	3816	-1188	1902	3728	2810
L15	2659	-0184	3291	-3934	2865	1485	-0025	-0177	0618
L16	1393	0516	3076	-0738	3636	-1235	2621	2392	2821
L17	3336	3143	1546	1752	1575	-0491	-6283*	-4857	1415
L18	3217	-5754*	0596	-2661	0607	4465	4332	4790	2844
L19	0205*	3589	1442	-1144	2180	-0262	-4064	-3377	-0923
L20	2467	2018	0713	-1985	4180	1274	-1172	-1582	2280
L21	5220	5755*	2660	1614	-2766	2289	2968	5450*	5856*
L22	1471	-7181**	1967	-1174	-3887	4317	-4150	3237	4902
L23	2724	5841*	0645	2365	2367	-1304	-2131	-0694	0810
L24	1475	3650	2063	1497	0589	-3933	-1528	-0208	5142
L25	3123	4800	1181	-1915	3645	-2519	-3649	-2899	-0750
L26	1761	4837	2661	-0579	4403	-2354	-2575	-3161	0136
L27	4202	-2765	6292*	5170*	-1020	2271	2945	5482*	3748
L28	1000J	-2494	5498*	2110	-0224	-1330	2854	3328	0514
L29	2691	1000	0068	1719	3242	-5911*	5474*	-5192	-4579
L30	5498*	-0068	10000	4026	0835	-1513	-0208	2680	1716
L31	2110	1719	4026	10000	-0100	1433	-1495	0000	3782
L32	0224	3242	0835	-0100	10000	0227	-1612	-3931	-3228
L33	1330	-5911*	-1513	1433	0227	10000	3467	3673	3673
L34	2654	5474*	0209	-1495	-1612	4524	10000	7512**	0458
L35	3328	-5192	2680	0000	-3931	3467	7512**	10000	2887
L36	0814	-4579	1716	-3782	-3229	3673	0458	2887	10000

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